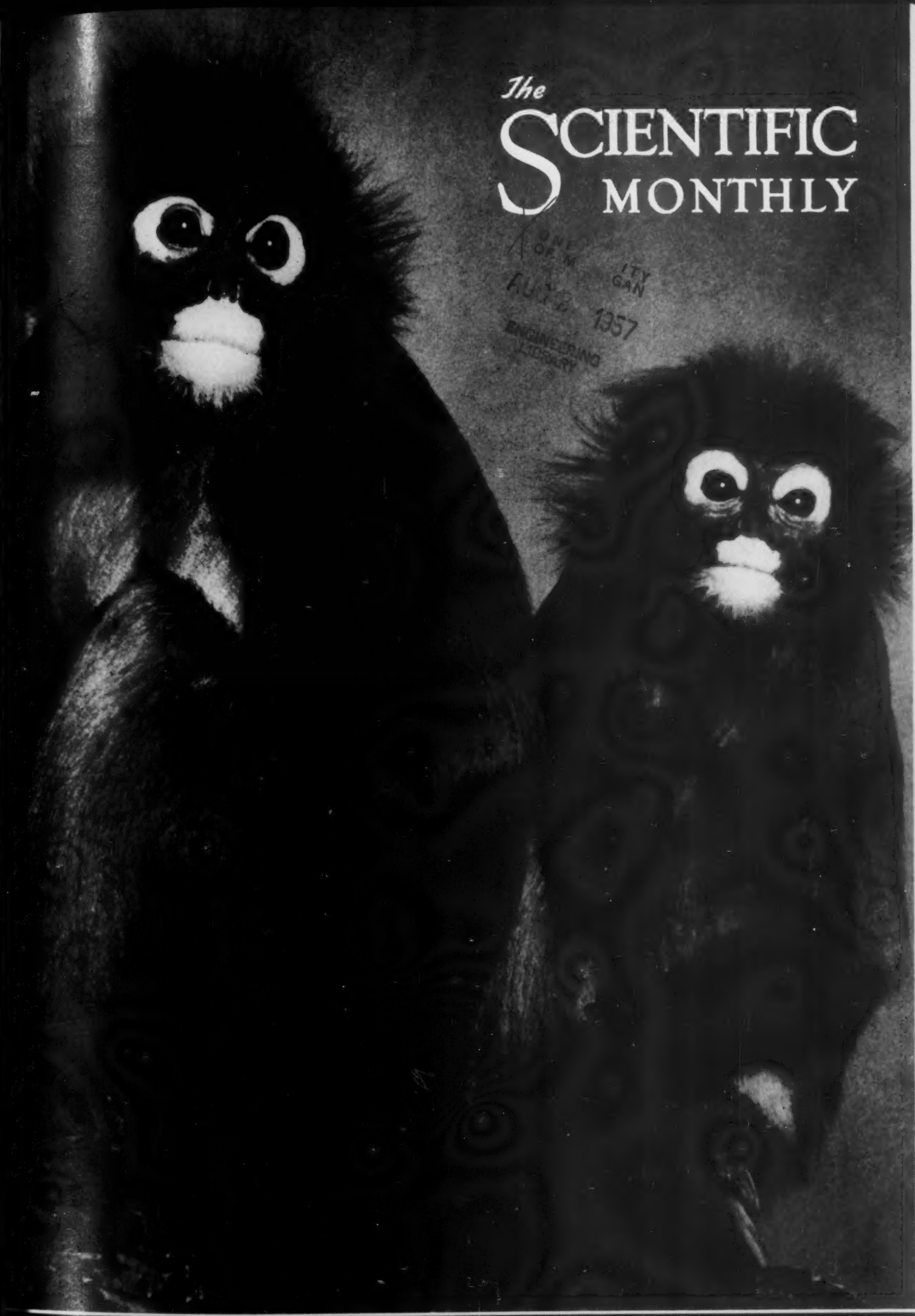
The SCIENTIFIC MONTHLY



VOL. 83 NO. 2 AUGUST 1956

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Cover: Mother and Child

[*Courtesy J. Musser Miller, LaGrange, Illinois, see page 65*]

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Science and Technology

(From the month's news releases; publication here does not constitute endorsement.)

Sound Analyzer

An instrument that is called a soundscope measures over-all sound levels; operates as an analyzer, measuring sound in each of eight octave bands to determine noise peaks; and checks sounds in narrower frequency bands. Electric and acoustic calibrators are built into the portable, 20-lb unit. When used as a sound-level meter, the instrument picks up noise through its microphone. The sound-pressure level is measured by passing the electric signal through attenuators and amplifiers to the meter, which is calibrated in decibels. Measurement range is from 24 to 150 db. In the analyzer section of the instrument, noise is filtered into any of the octave bands from 75 to 19,000 cy/sec. Noise peaks in each of these bands can then be measured individually. For finer analysis, by frequencies within the octave bands, continuously variable filters are utilized. (Mine Safety Appliances Co., Dept. SM, 201 N. Braddock Ave., Pittsburgh, Pa.)

Anesthesia Monitor

An instrument called an anesthograph measures the depth of anesthesia of patients undergoing surgery. The instrument, which incorporates an electrocephalograph and an electrocardiograph, simultaneously records brain-wave patterns and heart-action tracings. (Edin Co., Inc., Dept. SM, 207 Main St., Worcester, Mass.)

Dispersions

An alkyd resin dispersion that contains semicolloidal graphite that forms a durable, corrosion-resistant, dry lubricating film is included on a revised list of dispersions issued by Acheson Colloids. Carriers and diluents are given for dispersions of graphite, molybdenum disulfide, mica, vermiculite, zinc oxide, and acetylene black. (Acheson Colloids Co., Dept. SM, Port Huron, Mich.)

Hospital Scale

Checking the weights of patients in hospital beds without disturbing them is possible with a new portable electric scale. The apparatus, designed for use with simple lugs that can be clamped on any bed, reads in grams up to about 550 lb and has a 10-step scale with 50 g per division. (Lima-Hamilton Corp., Dept. SM, Philadelphia 42, Pa.)

Laboratory Furniture

A Duralab publication illustrates and gives specifications for center, wall, and titration tables; fume hoods; storage cases; distillation racks; and other equipment. (Duralab Equipment Corp., Dept. SM, 979 Linwood St., Brooklyn 8, N.Y.)

Throw-Away Catheterization Set

A disposable Cath-urine set for female catheterization is sterile and consists of catheter, polyethylene collection bag, and record card (American Hospital Supply Corp., Dept. SM, 1210 Leon Place, Evanston, Ill.)

Chemical Apparatus

A catalog of apparatus and accessories for chromatography and electrophoresis has been published by Scientific Glass Apparatus. Such items as chromatocabs, drying ovens, fraction collectors, desalters, and desitometers are described. (Scientific Glass Apparatus Co., Inc., Dept. SM, 100 Lakewood Terrace, Bloomfield, N.J.)

Molybdenum Borides

Refractory molybdenum borides are described in a recently issued six-page bulletin that gives applications; chemical, physical, and mechanical properties; and preparations of molybdenum boride compounds. Data are given for four molybdenum borides and seven multiboride systems. The latter include compositions of molybdenum borides with borides of nickel, chromium, cobalt, iron, titanium, tungsten, and zirconium. Outstanding properties of these materials are high melting points, high hardness, resistance to corrosion and abrasion, and high electric conductivity. Present and potential applications of the compounds include their use in machine parts that are subject to abrasion and corrosion and in rocket parts. (Climax Molybdenum Co., Dept. SM, 500 Fifth Ave., New York 36)

Filters

Optical wedge filters showing linear characteristics over a wide spectral range are available from Axler Associates. Filters can be produced to cover the spectral range of 0.240 to 2.7 μ in increments of 0.100 to 0.300 μ. They are available in sizes ranging from 1½ in. by 3 in. to 2 in. by 6 in. Peak transmissions and half widths are within the tolerance of the standard 2-by-2-in. ultraviolet, visible, and infrared transmission filters. (Axler Associates, Dept. SM, 102 43 Ave., Corona 68, N.Y.)

Carbon-14 Compound

Histamine-(2-*ring*-C-14)-dihydrochloride has been added to the list of the commercially available radioactive carbon compounds. This material is used in the study of amino-acid formation and metabolism, allergic reactions, and general body physiology. It is available at an activity of 1 mc/mmole. (Nuclear Instrument and Chemical Corp., Dept. SM, 229 W. Erie St., Chicago 10, Ill.)

THE SCIENTIFIC MONTHLY

AUGUST 1956

Protogenetics from Adam to Athens

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THE first roots of genetics—several thousand years before the subject's name was invented—were started and nurtured by man's longing to identify himself qualitatively with previous and succeeding generations. Further, man had genuine and practical interests in propagating the animals and plants best suited to his needs. No doubt introverted and egotistic concerns were tremendous in the first instance; economic stakes were high in the second—no less than life itself. The task was never easy nor clearly laid out. Scientific bases were either not known or only slightly understood. And, although the attempts were generally frustrating, they were manifest in nearly all those ancient civilizations that left even a detritus of broken pottery and forgotten monuments.

Babylonia, India, China, Israel, Egypt, and Greece wondered and worried about the transmission of hereditary features. Their art, literature, and lore bespeak these interests and chronicle many of their attempts at solution. Even when these peoples did not look for laws and principles, they sometimes left casual data that showed desirable results of breeding practices or prolonged and studied concern over genetic problems. A statement made by an unknown Hindu sage goes to the heart of the fundamental problem (*1*): "In thy offspring thou art born again; that, mortal, is thy immortality."

This study is an attempt to collect many of the data and to synthesize the story of early genetic practices from primitive times to Aristotle's Athens. The word *genetics,* here an anachronism, is supplanted by *protogenetics.* In a few instances, chronological boundaries are violated because the place of the focus is substantially out of harmony with time. Indeed, both "ancient" and "primitive" men are still with us. Primitive tribes in remote regions still carry on their neolithic practices; and "prehistoric" men, in isolated areas, persist in their own delayed ethnology and primitive sociology. Consequently, those human achievements that include direct or indirect evidence of protogenetic practices are considered in this study.

Of course, the field and its various problems were not defined and labeled as so many segments to be mastered, but several aspects of man's purposeful efforts and partial understanding can now be detected in retrospect, namely: (i) recognizing an over-all dim picture of qualitative transmission; (ii) accomplishing effective selection; (iii) probing environmental influences and postulating the related "theory of acquired characteristics"; (iv) inventing "pangenesis"; (v) alluding to real and fancied hybridization; (vi) practicing inbreeding; (vii) trying to fathom the principles of sex determination; (viii) wrestling with the twinning problem; and (ix) noting other phenomena related to the general problem. We shall consider these varied attempts one at a time.

"Like Begets Like"

The line between superstitious and intelligent approaches to these problems was fuzzy. However, the keystone "like begets like"—although not always reliable—was used early. In ancient India, perhaps before the blooming of Greece, the sacred books stated simply but firmly this idea when they said "That [the seeds of] one [plant] should be sown and another produced cannot happen. . . ." Again, in a hymn that invoked a special blessing on the Hindu bride, hereditary and congenital diseases are negatively feted (*2*): "The diseases which follow the bridal procession from her own clan, let the venerable gods drive them back. . . ." Even earlier, the foundation stones of protogenetics are evident in Genesis 1. The broad, fundamental idea is stated again and again in that first book of the Bible when it is recorded that the various creatures "brought forth, according to their own kinds."

Furthermore, Jewish practices were based on this first tenet of genetics. At least, they formulated laws on hemophilia with either uncanny wisdom or unusual luck: if two successive children died of circumcisional bleeding, the rite was forbidden for the family's subsequent sons (*3*, p. 70). The Hebrews marked certain imperfections as genetically dangerous—for example, the marriage of a man into an epileptic family was forbidden (*4*). Aristotle, on at least one occasion, in his *History of Animals* succinctly lays out a like-begets-like plan of hereditary derivation, hopeful and naive (*5*, VII, 6, 585[b]): "From deformed parents come deformed children, lame from lame and blind from blind, and, speaking generally, children often inherit anything which is peculiar in their parents and are born with similar marks such as pimples and scars." We need not castigate him for these faulty conclusions, because he detects his own inadequate explanation and proceeds to exonerate himself as he continues, "Such cases, however, are few; for the children of cripples are mostly sound [and] . . . while children mostly resemble their ancestors, it sometimes happens that [there is] no such resemblance. . . ."

Selection

Early tillers of soil, owners of flocks, and prosaic choosers of plants and animals to grace hearths and provision larders were all practical protogeneticists. They must have promulgated, without fuss or fanfare, a program of improvement by phenotypic selection. With subject materials still semiwild and in a state of marked heterozygosity, the program was especially effective, and its results were sometimes spectacular. We are impressed now by the degree of divergence produced. By divergences I mean those few startling data that are chiseled in the lithic art of Egypt, baked in the clay tablets of Babylonia, worked into the beautiful bas-reliefs of Assyria, and fashioned on the pottery of the American Indian. The artistic representations indicate that most ancient civilizations were proud indeed of the merits of their selection. Of course, these civilizations were not cognizant of the principle or principles involved, but they were ever or often conscious of the appearance of new and better traits, and they "knew" somehow that when a desirable feature was discovered it might be perpetuated. That was a real boon to protogenetics.

The date palm, probably since Babylonian times, has been hand-pollinated. Bas-reliefs on monuments depict priests in ceremonial attire doing the task. Early agriculturists learned that one male tree was sufficient to fertilize scores of female trees. Hence, few males were needed; date production was increased on a given tract of land. This was good, for arable land was scarce.

It seems to follow that selection was practiced. The best types of male trees were cultivated, and those females that produced the most delectable dates were selected to furnish seeds for planting. Although shoots were often used for reproduction, seeds were also employed for propagation. The results of the seed planting were probably baffling, and the large number of date varieties was chaotic. Recently Roberts stated that even now more than 400 distinct varieties of dates are reported from only four oases in the Sahara (*6*). With the essentials of plant sex in their workaday hands, this could have been the opening wedge to extensive hybridization in other economic plants. It was not. Date pollination persisted on the level of religious and poetic expression; perhaps no more. Although the good effects were fully appreciated, the real understanding of plant sex had to wait for 16th- and 17th-century biologists. Selection went on, however, without general concepts of sex, and cells, and chromosomes, and genes.

There is no telling what numbers and kinds of plant improvements were discovered, perpetuated, and then lost again to history because of man's preoccupation with other matters. May we assume that seeds, veritable life insurance here, were saved and guarded even in the most trying times with unusual vigilance? This seems to be a reasonable assumption, but these early peoples were usually not archivists. Their "records" were usually accidental; their motives were frequently religious or esthetic when they depicted their varieties of domesticated plants and animals. The artifacts remain

Fig. 1. Pre-Inca burial vases decorated with maize. The long straight rows of kernels reflect the success of early selection. [From the *Journal of Heredity*, by permission]

to tantalize us in stony silence. At best, they whisper the interrupted story of selection, remote and incomplete. Yet we are amazed by those few understandable syllables.

American Indians developed and improved maize (Fig. 1)—not one variety, but several. Some were cultivating miles of cornfields when Columbus arrived (*7*), and their western cousins of the upper Missouri Valley had 104 varieties of corn; four of the varieties were sweet corn (*8*). Ancient Egyptian selectors had been active too; they had a host of garden vegetables and fruits, already far removed from their closest relatives in the wild state. Egypt had two varieties of lentils, 11 kinds of melons, and eight types of cucumbers (*9*). Selection not only established these several varieties but elevated original parent stocks from wild antecedents. De Candolle, an expert on the history of cultivated plants, listed 32 common plants with no known ancestors in wild species and 40 more that have questionable genealogies (*10*). So the story goes: potatoes from the Peruvian Andes; barley and wheat from the clearings of neolithic Europe and Asia (*11*)—perhaps several strains. There are various opinions concerning the number of kinds of wheat in prehistoric granaries (*12*, pp. 335–336; *13*; *14*); that there was more than one variety is generally agreed. Again, the fact that varieties did exist so early emphatically tells us that a long and purposeful practice of selection produced these results. When we find the carving of primitive wheat on the tomb of King Zer (*3*, p. 61) in the royal burying grounds near Abydos, we know that the Egyptians had a domesticated and standardized wheat 30 centuries before Christ (*15*). Furthermore, the desire and mental acuity of hundreds of individual planners made possible, and preceded, the carving of that plant figure. In fact, early peoples actually guided the plant's evolution.

Selection produced results just as spectacular in the animals of some of these ancient civilizations. The dog, an early and ubiquitous guest in man's home, was pushed to wide morphological divergences by selection. Thanks to early Egypt, we have stone-engraved evidence to prove it. Egyptian monuments bear canine figures ranging from the stilt-legged forms of a wolf-hound cast (Fig. 2) to an achondroplastic dachshund motif (Fig. 3), both considered extremes even by modern dog breeders. Intermediate forms were also markedly distinct (Fig. 4). Darwin says that ancient Egypt, perhaps 5000 years ago, had seven definite breeds of dogs (*12*, p. 17). Primitive man started that concatenation of selection early; historical man encouraged and accelerated it. Modern man sometimes feels that he has done it all.

Sheep and goats have been herded for 8000 years, the cow perhaps as long ago as 10,000 years, and the swine only slightly less (*16*). Selection certainly made progress even in remote centuries. Where art and literature were not conscious of these improvements, some civilizations left no descriptive data. Yet we can infer that selection and improvement continued. In ancient Palestine, for instance, the Pentateuchal codes decreed that fields be given

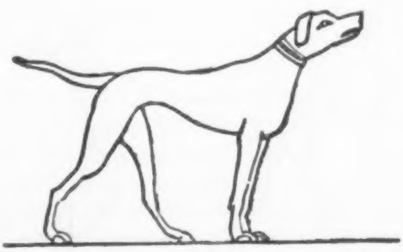

Fig. 2. Dog of wolfhound proportions from Ancient Egyptian monument. [Reprinted by permission of Dodd, Mead and Company from Rawlinson's *History of Ancient Egypt*]

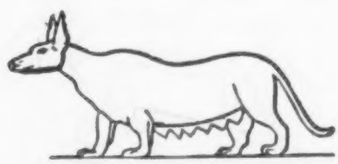

Fig. 3. Figure from ancient Egyptian monument suggesting certain features of the modern dachshund. [Reprinted by permission of Dodd, Mead and Company, from Rawlinson's *History of Ancient Egypt*]

sabbatical rests (*17*). When the better land tracts were fallowed, feed shortages prevailed, and flocks were necessarily reduced. Consequently, inferior animals underwent septennial culling in some sectors; selection was inevitable, and its effects were inexorably cumulative.

New qualities and features were continually presenting themselves. Gene and chromosome mutations, polyploidy, outcrossing, inbreeding, and perhaps some deliberate hybridization produced an array of new characters, some of which were radical modifications. The prototype of China's fat-tailed sheep (Fig. 5), an oddity in the Western world, was already old in ancient Greece, for Herodotus, about 440 B.C., (*18*, p. 266) described one type of Arabian sheep that "had a tail so heavy that it is supported and protected by a wooden truck."

Horse selection was well under way long before the first historiographer began his task. Stone Age man may have tamed the animal; one of his engravings showed a horse's head wearing what seems now to have been a halter. Even more convincing, a horse-breeding record of about 6000 years ago engraved on an Elamite seal (*19*) seems to tell a running story of breeding sequences that featured mane and profile variations (Fig. 6). By the time Egypt's Pharaohs had enjoyed their first crescendo of glory, the horse—at least one breed—had become a beautiful and spirited creature reflecting its royal master's pride and vouching again for the legions of now anonymous breeders whose intelligent efforts in protogenetics developed the animal (Fig. 7). Indeed, these beautiful beasts were far removed morphologically from the Aurignacean ponies of the Stone Age (*20*), although they were probably descendants of them or similar small equine animals.

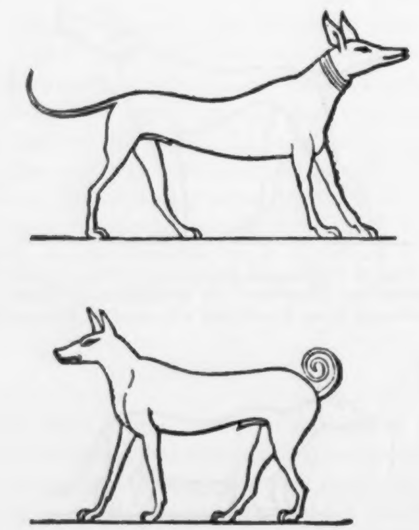

Fig. 4. "Intermediate" breeds of dogs from Ancient Egyptian monuments. [Reprinted by permission of Dodd, Mead and Company from Rawlinson's *History of Ancient Egypt*]

Yet selection had shortcomings—even frustrating reversals of form. Theophrastus (*21*, II, ii) admitted this and clearly stated some results that left him baffled: "And while all the trees which are propagated . . . by some kind of slip seem to be alike in their fruits to the original tree; those raised from the fruit, where this method of growing is also possible, are nearly all inferior while some quite lose the character of their kind as vine, apple, fig, pomegranate, and pear." Natural cross-pollination and extraordinary heterozygosity confused and partially invalidated fruit and seed selection. That problem still challenges the breeder of pomaceous fruits.

On Environmental Influences

The empirical approach seemed to dictate simple answers to complex problems. Effects of environment seemed to be impressed on developing organisms. Imagination and hearsay took observable environmental effects far afield, particularly among the Greeks.

Theophrastus (*21*, II, ii) believed that ". . . differences in situation and climate affect the result. . . . The soil [at Philippi] seems to produce plants which resemble their parent; . . . a few kinds in some few places seem to undergo a change. . . ." He reported the highly doubtful transmutation of a cereal grain from one genus to another. He wrote, "There are . . . modifications due to feed and attention of other kinds which will cause the wild to become cultivated, or again cause some cultivated kinds to go wild. . . . Some say that *wheat has been known to be produced from barley,* and barley from wheat, or again both growing on the same stool." His embarrassment seemed to overtake him and he hastened to exclaim: "These accounts should be taken as fabulous." On another occasion (*21*, II, iv), he stated, without qualification, that "Wheat turns to darnel, one-seeded wheat and rice-wheat change into wheat *if bruised before they are sown* . . . in the third year." Whether or not he believed this, Theophrastus followed it with a statement of recapitulation wherein he made claims more modest and general, some of which are supported by modern experiment (*22*): ". . . [in growing plants] when a change of the required character occurs in the climatic conditions a spontaneous change in the way of growth ensues." Aristotle

(23, II, 4, 738[b]) probably said the same, in essence: ". . . foreign seeds produce plants varying in accordance with the country in which they are sown." At least some Greeks held to the transmutation from one genus to another in the animal kingdom. Theophrastus (*21*, II, iv) reported ". . . so also changes in the nature of the ground produce changes in animals, for instance, the water snake changes into a viper, if the marshes are dried up." The following passage from Aristotle's *History of Animals* (*5*, III, 12, 519[a]) suggests Lamarckism. "Some animals change the color of their hair with a change in their drinking water, for in some countries the same species of animal is found in one district, white, and black in another. . . . And in Antandria there are two rivers of which one makes the lambs white and the other black. The river Scamander also has the reputation of making lambs yellow. . . ." Homer too may have had the same idea—and much earlier, of course—when in his *Odyssey* (IV, 85) he said that the oxen of Scythia have no horns because the climate is too cold.

Perhaps some of these Greeks may not have implied an acquired-characteristic explanation. However, Hippocrates, the "father of medicine," did insist on such an explanation. He believed that acquired characteristics in man were transmitted to his offspring. In his "Airs Waters Places" (*24*, XIV, p. 111) he stated the substance of the theory that was later to be identified with Lamarck. He said, for example, that "[in a certain region] as soon as a child is born they remodel its head with their hands, while it is still soft and the body tender, and force it to increase in length by applying bandages and suitable appliances, which spoil the roundness of the head and increase the length. Custom originally so acted that through force such a nature came into being; *but as time went on the process became natural, so that the custom no longer exercised compulsion.*"

There is evidence also that the ancient Jews accepted the environment as an instigator of genetic change. An account in Genesis (30: 32–42) relates the effect of conspicuously displayed spotted rods on the production of spotted lambs. Rods of poplar, almond, and plane, partially peeled of their bark, were placed in the breeding and watering areas so that "the sheep beheld the rods, and brought forth spotted, and of divers colours, and speckled."

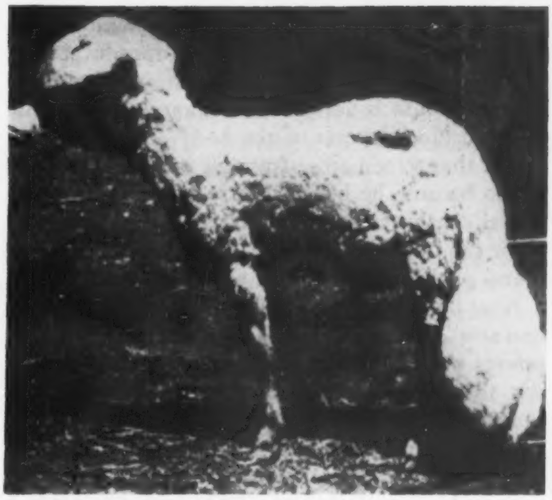

Fig. 5. Fat-tailed sheep of China, perhaps similar to a breed described by Herodotus, already developed prior to his time. [Reprinted from *Yearbook of Agriculture 1936*, by permission]

Pangenesis

The acquisition of new characteristics from an organism's environment constituted a formidable claim. The transmission of the newly acquired traits to succeeding generations needed a special explanation. The Greeks thought of that too. The name *pangenesis* was minted by Charles Darwin in the mid-19th century, but the idea of the theory, with frequent defensive outbursts of support, was common in early Greek writings. Zirkle (*25*) says it appeared 90 times in various guises, in several countries, before Darwin used it (*26*). Darwin humbly called it "provisional"; the Greeks accepted it with reservations.

Democritus, the atomist, (about 400 B.C.) was one of the early Greeks who hinted at such a theory (*27*, p. 289) when he said that the "gametes" are made up of the most important parts of the body: bones, flesh, and sinews. He came somewhat closer to our modern view when he stated that the female gametes are "collections of atoms." Hippocrates (about 380 B.C.) was another champion of pangenesis. Neither by implication nor by innuendo, but by straight-forward phrases, he presented his theory for anyone to challenge. His words (*24*, XIV, p. 111): "For the *seed comes from all parts of the body,* healthy seed from healthy parts, diseased seed from diseased parts."

Aristotle was not so sure. In fairness, he probed about the problem, offering at times support, at other times criticism and doubt. A plant cutting grows to produce a *whole* plant; how might one explain that? he asked perspicaciously. He devoted 16 pages in his *Generation of Animals* (*23*) to the problem of the origin of semen, which to him is irrevocably tied to pangenesis. On at least one occasion he came close to postulating a particulate type

of heredity (*25*): ". . . semen is the mixture of a large number of ingredients, and in appearance the offspring take after that parent from whom the largest amount is derived." He thought the intense pleasure "in all parts of the body" during coition meant that semen arose from all parts. He thought so too because he believed, erroneously (or coincidentally), that mutilations and scars were inherited —for example (his example) a certain man with a brand on his arm passed it on to his son.

Now he moved to the other side of the problem and saw a different view. He noted that before they possess beards, or gray hair, men generate young; yet these structures and their unique qualities somehow cross the inheritance bridge. A man's voice, he continued, "from which nothing comes" (namely, no seeds or seed parts), transmits its peculiarities and idiosyncrasies to offspring (*23*, I, 18, 722ª). He suffered one more pang of doubt, in the same work (*23*, IV, 3, 769ª): "Again, for what reason is a child generally like its ancestors, even the more remote? None of the semen has come from them at any rate." As usual, Aristotle is fearful of premature conclusions.

In Hippocrates' time, as in Darwin's day, pangenesis cast little real light on the understanding of genetics. Our point is that these early Greeks were as energetically and intelligently attacking the mysteries of heredity as their successors did during the following 22 centuries. Their overwhelming disadvantage was that they had few or no valuable precedents.

Hybridization and Inbreeding

Hybridization may have been practiced 10,000 years ago—perhaps 25,000 years ago (*28*), but instances of man-controlled crossing are not often evident. Aristotle speculated on the problem and recognized some of its obstacles. He dwelt on three apparent levels of incompatibility (he could not know those genetic barriers that reside in the cell). "This [wide crossing] is possible when the periods of gestation are equal and conception takes place nearly at the same season and there is no great difference in the size of the animals (*23*, II, 4, 738ᵇ). He makes allusions to interspecific, intergeneric, and even interfamilial crosses. He does not insist that they have occurred, but seems to accept them on hearsay. He casually alludes to crosses between fox and dog (*5*, VIII, 28, 607ª; *23*, II, 4 738ᵇ), partridge and domestic fowl (*23*, II, 4, 738ᵇ), wolf and dog, and tiger and dog (*5*, VIII, 28, 607ª). Herodotus (*18*, p. 521) did not clarify the total picture when he reported that a mare foaled a hare.

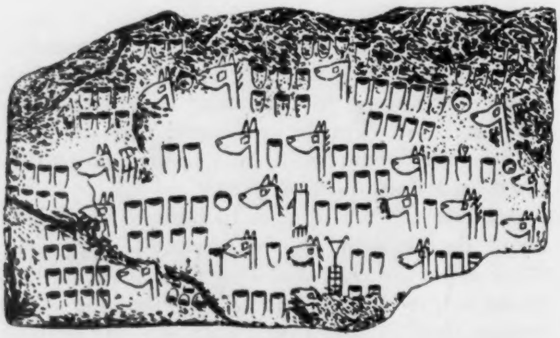

Fig. 6. Horse-breeding record engraved on a seal from an excavation near Ur in Mesopotamia. Note three kinds of profiles and three kinds of manes. Probably 6000 years old. [From W. Amschler, after de Mecquernem and von Scheil]

In the human family, inbreeding was probably the rule in primitive and ancient times. Lack of, or primitive, communication and transportation were certainly impediments to outcrossing. Primitive cultural and social patterns further tended to accentuate clan insularity. Inbreeding was inescapable; it became the established and standard guide to mating.

Among ancient Jews, hybridizing must have evoked fear and consternation, for Hebrews prevented its practice by strict and ominous precept. In Leviticus (19 : 19) we read "Thou shalt not make thy cattle to gender with beasts of any other kind." Even louder and clearer, Genesis (30 : 35, 36) records that Laban ". . . *separated* . . . the she goats, and the sheep, and the he goats, and the rams of *divers colors,* and spotted; and all *the flock of one color* . . . he delivered into the hands of his son. . . ." Thus space became genetic insulation. Jewish law forbade sowing two kinds of seeds in the same field (Leviticus 19 : 19). No hybrid grains here, and no mules.

Among men, there should have been no half-castes in Palestine. Tribal endogamy was striven for by Israel's lawmakers (*29*), and marriage of close relatives was common practice. Although special laws were formulated to allow an outsider to marry into a certain blood lineage (*30*), there were unauthorized matings between Jews and members of peripheral populations. Ezra brought forth the whole problem of Jewish outcrossing in a dramatic presentation of the facts and a public denunciation of the practice (*31*). Human nature being what it was, dignitaries who could afford to wink at the law, as well as common people who in periods of laxity forgot the precept, were guilty.

Human inbreeding was condoned and even encouraged in Egyptian mores. Brother-sister combinations were fairly common among them, and in

Greece uncle-niece unions were countenanced (*25*). Mother-son marriage was not allowed, however, as Zirkle has stated (*25*); after all, that was the heart of the trouble and the very nub of the plot in *Oedipus Rex,* the tragedy of Sophocles. An ancient civilization that took vehement exception to close inbreeding was India. In the ancient Hindu law (*1*), we read that a man should not marry "one descended from his maternal ancestors within the fifth or . . . paternal ancestors within the seventh degree. . . ." Yet, the caste system, by its very nature, promoted inbreeding within the broad limits of a caste.

Sex Determination and Twinning

No game of theorizing has been played with so much zest and by so many authorities as that of sex determination. The present values of ancient explanations here are relative to their historical interest. One Hindu formula (*1*) to help a swain choose a boy-generating mate went like this: "He shall seize the hand of a girl . . . [who] should have at her neck two curls turned to the right . . . [and be assured] she will give birth to six men." Another (*1*) required fasting and special treatment of the would-be mother: "[After a special fast, he should insert] . . . into her right nostril . . . an herb, [now] seize her thumb if he desires only male children . . . [or] the hand on the hair side together with the thumb . . . [if he desires both male and female children]."

Heat and cold were sometimes considered the environmental variables that tipped the scale toward maleness or femaleness. Temperature extremes were often employed by the early Greeks to explain internal functions of the animal body. Therefore, the establishment of temperature as the pivot upon which turned the determination of sex is no complete surprise to us. Empedocles felt that regions of the womb varied in temperature and that if "seed" became lodged in a higher-temperature area a male would develop; in a cooler region, a female (*27,* p. 193). Since the male was more perfect, according to Empedocles (*32*), it developed in greater heat, ". . . and for this reason [because of the heat] men are swarthy and more shaggy." Democritus thought temperature had no influence whatever. He felt that the seed, male or female, which dominated at the time of union would determine the embryo's sex (*27,* p. 289). For this statement Aristotle gave brief applause (*23,* IV, 1, 764^{a}). ". . . the theory of Democritus would be the better of the two, at least as far as it goes, for it seeks for the origin of this difference. . . ." Ultimately Aristotle went on with his own hypothesis (*5,* VI, 19, 573^{b}, 574^{a})—one that was never completely resolved or narrowed beyond the broad pale of winds, waters, and rams: "[In sheep, sex] depends on the water [which the ewes] drink and *also on the sires.* And if they submit to the male when the north winds are blowing they are apt to bear males; . . . south winds . . . females." On the same theme, on another occasion, he wrote (*5,* VI, 19, 574^{a}) "Such as bear females may get to bear males, due regard being paid to their looking northward when put to the male." On yet another occasion he seems to beg the question when he says (*23,* IV, 2, 767^{a}) ". . . so small a thing will sometimes turn the scale . . ." in sex determination.

Despite his own insecure position, Aristotle criticized his compatriots Empedocles and Anaxagoras for their inadequate explanations of the phenomenon. Anaxagoras, as well as the ancient Hebrews, believed (*25*) that "the dexter testis . . . produced the dominant sex, the sinister one female." Even though wind direction was Aristotle's point of departure, he worried Empedocles for his hot-and-cold hypothesis. He had unshakable confidence now, for he had experimental evidence to bolster his protests (*23,* IV, 1, 764^{a}) ". . . male and female twins are often found *together in the same part of the uterus*; this we have observed sufficiently *by dissection* in all the vivipara. . . ."

Twinning was destined to remain a mystery as long as gametic union, cleavage, and the embryogenesis of a single offspring remained unknown, but speculation was rife. Twinning had long been noted and duly respected. Just as the Old Testament records ambidexterity (for example, Judges 20 : 16) and polydactyly (for example, Kings 21 : 20), it also alludes to twins in Genesis (38 : 27).

According to Empedocles, twins and triplets re-

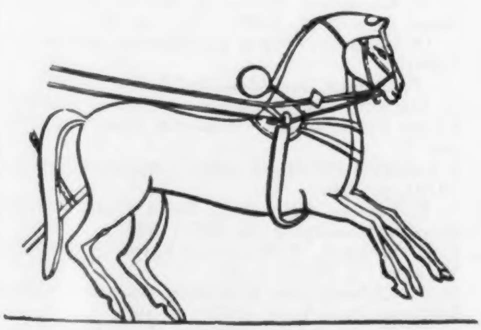

Fig. 7. Horses depicted on ancient Egyptian monument. Already this animal was a far cry from the wild horse of pre-historic times. [Reprinted by permission of Dodd, Mead and Company from Rawlinson's *History of Ancient Egypt*]

sulted from an excess of semen (*27*, p. 193), while Aristotle looked for the cause in diet (*5*, VI, 19, 574[a]). The latter said that twins in sheep and goats may be due to richness in pasturage. Then he deftly added a genetic suggestion: rams and he-goats may vary in their ability to beget twins, and ewes and she-goats likewise may vary in their frequency of conceiving them.

Abnormalities and Mutations

That pattern baldness is sex-limited was reported by both Aristotle and Hippocrates (*25*). The results were correctly set down for what they were; physiological explanations, of course, were wanting for 22 centuries. Empedocles maintained that monsters were due to excess or deficiency of semen (*27*, p. 193). Democritus felt that colliding "seeds" that had entered at different times were the authors of abnormalities (*27*, p. 307). Consistent with his temperature theme, previously mentioned, he attributed miscarriages to south winds that prematurely expanded the womb.

Radically new traits (mutations), especially deleterious ones, must have been generally disquieting. Theophrastus reported (*21*, II, iii) that ". . . soothsayers call such changes portents." Monstrosities in the following instance gave Aristotle deep trouble (*23*, IV, 3, 767[b]). He seems to have woven a web of frustration with the available threads of conflicting data and opinion on human genetics; he ended up with a surrender to them. He succinctly set forth the inadequacies and failures of all protogeneticists in a scholarly lamentation: ". . . if we assign only one sort of cause it is not easy to explain all the phenomena; the distinction of the sexes; why the daughter is (or can be) like the father and the son like the mother, and again, the resemblance to remote ancestors, and further, the reason why the offspring is sometimes unlike any of these but still a human being; but sometimes, proceeding along these lines, appears finally to be not even a human being but only some kind of animal that is called a monstrosity."

Until Mendel's logic and mathematics exposed the basic principles of genetics, there was no starting point. Even Galton (about 1890), with his mountains of data, failed to approach the solution. We are not surprised or very disheartened to find such intricate and impressive word-juggling here in ancient times while no solid conclusions evolved. With these delimiting circumstances in mind, listen to Empedocles attempting valid dicta on the subject (*27*): "If both male and female seed is hot, the child will be male and like the father; if both seeds are cold, it will be a female and like the mother. If only the father's seed is hot, it will be male and resemble the mother; if only the mother's seed is hot the offspring will be female but resemble the father." Then he introduces a safety device to take care of all other contingencies: "If children resemble other people; then the mother's imagination has done it."

Conclusion

Thus the ancients started several small fires to illuminate their adventures into protogenetics. They anticipated Lamarck's "transmission of acquired characteristics" and Darwin's "pangenesis," neither of which was destined ever to light up the world. Despite their shortcomings, we must admit that ancient biologists wisely used some of the concepts of genetics, and we must commend them for ceaselessly trying to find and to understand the principles involved. They were the protogeneticists.

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Mother and Child

The white-mouthed langurs shown on the cover this month represent an interesting animal that is native to the high forests of Burma, Siam, and Indochina. Langurs, or leaf-eating monkeys, are the common simians of India and southeastern Asia. Their slender bodies and limbs, their very long tails used for balancing, and their long hands curved like hooks for grasping enable them to run and leap through the trees with exceptional speed and agility. They seldom descend to the ground except for water and to raid cultivated fields.

This picture was made at the Brookfield, Ill., zoo by J. Musser Miller of LaGrange, Ill., and was one of several thousand entries for the 1956 Chicago International Exhibition of Nature Photography, which was sponsored by the Chicago Natural History Museum and the Camera Club of Chicago.

Caste and the Jajmani System in a North Indian Village

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ALTHOUGH there is a great deal of literature about the caste system of India, very little attention has been paid to its economic aspects (*1*). Most books and articles on caste have concerned themselves with the problems of its historical origin and development, with the rules and sanctions governing endogamy, food taboos, ritual purity, caste ranking, and the more dramatic injustices of untouchability. It is common in works about caste for the author to list the castes of a particular region with some account of the traditional occupation of each; but it is a curious fact that the author generally avoids what might logically seem to be a next step, an analysis of how these groups interact with one another in the production and exchange of goods and services. William H. Wiser, in his book *The Hindu Jajmani System,* was the first to describe in detail how such goods and services are exchanged in a rural Indian village. It is greatly to Wiser's credit that he was able to characterize *jajmani* relations *as a system.* Some knowledge of this system is crucial for an understanding of the economic aspects of caste in rural India (*2*).

Under this system each caste group within a village is expected to give certain standardized services to the families of other castes. A Khati (carpenter) repairs tools, for example; a Nai (barber) cuts hair; but they do not necessarily perform these services for everyone. Each man works for a particular family or group of families with which he has hereditary ties. His father worked for the same families before him, and his son will continue to work for them, the occupation or service being determined by caste. The family or family-head served by an individual is known as his *jajman* (*3*), while the man who performs service is known as the *jajman*'s *kamin* or *kam karne-wala* (literally, worker). These are the terms used in northwestern India; in other parts of India where the system prevails other terms may be used.

It is a characteristic of this system to operate without much exchange of money. For it is not an open-market economy, and the ties between *jajman* and *kamin* are not like those of employer and employee in a capitalistic system. The *jajman* compensates his *kamins* for their work through periodic payments in cash or grain, made throughout the year on a daily, monthly, or bi-yearly basis. *Kamins* may also receive benefits such as free food, clothing, and residence site, the use of certain tools and raw materials, and so forth. To Wiser these concessions represent the strength of the system and are more important than the monetary payments (*4*, pp. 6–11). Despite the increased use of money in recent years, the peasants nowadays tend to prefer grain payments to cash, since grain prices have risen so enormously in the past decade (*5*).

When Wiser wrote his book, he did not know how general or widespread this system might be, although he referred to some passages in the works of other writers which suggested that it had a wide range of diffusion. This conclusion is supported by more recent studies, which give evidence for much the same kind of system in eastern Uttar Pradesh (*6, 7*), parts of Malabar and Cochin (*8*), Mysore

District (9), Tanjore (10), Hyderabad (11), Gujarat (12), and the Punjab (13). Regional differences, of course, appear.

A major function of the *jajmani* system is to assure a stable labor supply for the dominant agricultural caste in a particular region by limiting the mobility of the lower castes, especially those who assist in agricultural work. If a *kamin* leaves the village, he must get someone to take his place, usually a member of the same joint family. This does not usually involve sale, and the *jajman* is not likely to object, as long as the position is filled. But such transfers are rare (*5*, p. 21; *7*, p. 135; *14*, p. 98). The *kamins* have valued rights and advantages which make them hesitate to move. We get a picture of this from the autobiography of a sweeper: "... my father's family have been serving a certain number of houses for the last few hundred years, from generation to generation. It was an unwritten law that if my family wanted to move out of the town to go somewhere else, they would have to find someone else in their place. In this matter the high castes have no choice as to who would work for them. If my people wanted to sell the work of the street in which they were working they could do so to another family of our own caste. The sale was only effected on condition that in that particular area no others of our community had any claim, and also that the people who bought it were satisfied that our family had been working there for at least two generations; the price would be fixed according to the income of the area. . . . But sales of this nature very rarely take place, as it means losing one's birthright and the family reputation. Also, this is the only means of livelihood open to us, and the richer the landlord we serve, the more prestige and honor we have . . ." (*15*).

Moreover, the community may put pressure on an individual to make him stay. Nehru cites the case of a village that instituted legal proceedings in a criminal court, seeking to insure that the village Lohar (blacksmith) should not migrate to another community, as he had threatened to do (*16*, p. 27), and Wiser describes the efforts of the people of Karimpur to keep a restless Dhobi (washerman) within the village (*4*, p. 123). Even if a *jajman* should be dissatisfied with his *kamin*'s work, he would find it hard to replace him. "It is not easy for an agriculturist to remove a family attached to his household and secure the services of another. For example, A, a barber, is attached to the family of B, an agriculturist. If for any reason B is greatly dissatisfied with the services of A and wants those of another, he cannot abruptly dismiss A. His difficulty will not be in dismissing him, but in finding a substitute. Each of these castes has its own inter-village council. Occupational castes have a developed trade unionism. . . . No one else would be willing to act as a substitute, for fear of being penalized by the caste *panchayat*. It may even be difficult for a number of families to join together and import a family belonging to that occupational caste from a different village. First, under these conditions of tension, an outside family would not come for fear of social pressure and ultimate ostracism for such an action. And if they do come, the caste fellows already in the village would make things very difficult, even unbearable, for them" (*11*, p. 60).

Not every village has a full complement of specialists. In a survey of 54 villages in the mid-Gangetic valley, Nehru found that no single caste occurred in all the villages surveyed. Camars (leather workers) were found in only 64 percent of the villages; Ahirs (herders) in 60 percent; Brahmans, Nais, Lohars, and Telis in 40 percent; Dhobis and Kurmis in 36 percent; Kumhars in 30 percent; and Baniyas in 16 percent (*16*, pp. 23–29). Nehru gives various reasons for the unexpectedly low figures of these caste groups. The Nai (barber), for instance, is a journeyman who goes from door to door and village to village. "No client needs him more than once a week and less than once a month. Also, the various festivals and ceremonies when his services are in urgent demand do not figure all too frequently in the village calendar. Hence alone or through a relation, one Nai can minister to the needs of more than one village; if the figures are an index, more than two villages" (*16*, pp. 24–25). The Dhobi (washerman), on the other hand, has a small representation because he serves primarily upper-caste or upper-class patrons. The womenfolk of most lower class families do the family wash. According to Singh, one seldom finds more than three Dhobi families in a village, and often only one catering to a group of villages (*14*, p. 93). Singh also says that the Bhangis (sweepers) are as sparsely scattered as the Dhobis, with their largest concentration in the towns (*14*, p. 95). Nehru explains that a single Baniya (merchant) can finance operations in villages within a radius of 10 to 20 miles or more; hence one need not expect to find Baniyas in every village (*16*, pp. 26–27). The supply and demand factor suggests that there must be some mobility, despite the localizing function of the *jajmani* system.

Jajmani rights, however, which link one to certain families, may be regarded as a form of property passing from father to son. Like land property, it is equally apportioned among brothers when they separate (*7*, p. 133). Certain problems eventu-

ate from this: "When a Lohar family multiplies and divides the work, each share comes to compass the work of fewer agriculturists unless they also multiply at the same rate. Of course when the latter multiply faster, the Lohars become responsible to a greater number of agricultural families, even though the extent of work may remain the same" (*7*, p. 130). The apportionment of *jajmani* rights may prove to be very unequal, as Reddy has shown. From a table giving the number of *jajmans* served by ten Lohar families in Senapur, it appears that one Lohar family serves only seven *jajman* families, while another serves 37 (*7*, p. 133). The rewards in grain and other benefits are of course proportionate. The *jajmani* system, then, provides some security in assuring one a position in society, but also gives rise to economic insecurity for some of the *kamins*.

In his pioneer work, Wiser summed up what seemed to him to be the advantages and disadvantages of the *jajmani* system in relation to the nation, the village community, the caste group, and the individual. On the whole, he emphasized the integrating and security-giving aspects of the system and described how it provided "peace and contentment" for the villagers (*4*, p. 187). Yet at other times, as we shall see, Wiser emphasized its attendant injustices. How the *jajmani* system affects the villagers who live by it, and what the future of the system may be in a developing money economy, are subjects that will be discussed in the latter part of this paper. First we will describe how the *jajmani* system functions at the present time in a particular village, Rampur, about 15 miles west of Delhi (*17*).

Jajmani System in Rampur

There are 150 households at Rampur, with a total population of about 1100. Twelve castes are represented in the village with the following distribution: 78 Jat families, 15 Brahman, 20 Camar (leather worker), 10 Bhangi (sweeper), 7 Kumhar (potter), 5 Jhinvar (water carrier), 4 Dhobi (washerman), 4 Khati (carpenter), 3 Nai (barber), 2 Chipi (calico printer or tailor), 1 Lohar (blacksmith), and 1 Baniya (merchant). Some caste groups often found in north Indian villages are not represented—for example, Ahirs, Telis, and Kurmis—but the list is quite representative and characteristic of the region.

The Jats are by tradition agriculturists and own all the land of the village, including the house sites, the land upon which the houses of the other castes are built. They are the principal *jajmans* for the other groups (Fig. 1). According to the traditional

Fig. 1. Two Jat village leaders discuss politics while smoking the hookah.

mode of ranking, the Brahmans are superior to the Jats. The Brahmans do have the dominant position in Wiser's village of Karimpur, where they are the landowners and number 41 families in a population of 754 (*4*, p. 19). But in Rampur the Brahmans are occupancy tenants of the Jats and are subservient to them.

The caste groups of Rampur have traditionally been related to one another through the mutual obligations of the *jajmani* system, the rules of which have been codified. Table 1 is an extract from the *wajib-ul-arz,* the customary law of Rampur, which specifies the kinds of work to be done by the different caste groups and the rates of compensation. The provisions of the *wajib-ul-arz* have legal effect, for British legislation continued to support these customary rules under civil law (*4*, pp. 14–15).

It may be noted in Table 1 that various rights and duties are specified in connection with weddings. Marriages are the high points in the social life of a village and represent a great expenditure of wealth by the families concerned. All the castes, or most of them, are brought into some connection with a wedding, in which the importance of the family and the village are demonstrated, and in which a *jajman*'s ties with his *kamins* may be strengthened. The same is true, to a lesser extent, of funerals and other *rites de passage,* as well as the village festivals. The service ties of the various caste groups are indicated in Table 2 (*4*, p. 70 ff.; *15*, pp. 13–15; *18*).

Thirty or 40 years ago a Khati at Rampur worked for his *jajman* all the year round. His work consisted of making plows and repairing

them in the fields, and making plow yokes, three-legged stools, legs for string cots, and various farming implements. The wood was supplied by his *jajman* (*19*).

The traditional payments for this work are specified in Table 1, but informants gave a somewhat different itemization as follows: (i) 45 *sirs* of grain from the wheat crop (in the dry season); (ii) as much wheat fodder as one person can carry (in the dry season); (iii) as much *jowar* (millet) fodder as one person can carry (in the rainy season) or (iv) 1/2 *maunds* of green fodder (gram or peas).

A common form of payment, as specified in items (ii) and (iii) above and in the barber's list of rights in Table 1, is the provision that a man may take home from the crop as much grain as he can carry by himself. This is, of course, an elastic amount. A generation ago the village Lohar carried such a heavy load that he vomited blood on reaching home and died instantly.

In addition to the grain payments received from each *jajman,* a Khati also gets payment in cash or kind for noncustomary services such as the making of wheels, planks, handles of milling stones, and so forth. Daily meals are provided while the Khati is working at wedding preparations for a *jajman*'s family, cutting the wood for fuel, and so forth, and he is feasted at the wedding itself and given 1 rupee (*20*) thereafter. Interservice relationships exist between the Khati and Nai, Dhobi, and Kumhar families. Each of the Khati families acts as *jajman* toward one Camar and one Bhangi family, which provide services for them and work at their weddings, when both families are feasted and given 1 rupee each.

While *jajmani* services are still exchanged, cash payment for carpentry is increasing, and *jajmani* ties have weakened. The Khatis have fewer *jajmans* than formerly. They seldom repair plows in the fields nowadays, and they are slow in completing jobs required by their *jajmani* obligations. The *jajmans* find that if they want to get work done on time, it is better to pay something in cash as well.

The famine of 1944–45 damaged the *jajmani* relationships between the Khatis and the Jats. Since grain was scarce, the Jats decided to reduce the customary dues. The village *panchayat* accordingly announced that the grain payments would be half the traditional amount that year. The Rampur Khatis and Lohars did not agree to these conditions and said that they would not work for their *jajmans* if they insisted on such terms. Six Jat families then broke off *jajmani* relationships with the Khatis and now do their own work, or else get it done by cash payments. Three of the Jat families have taken up carpentry. One of these families is dependent on carpentry as a full-time profession, while the other two are on a near-professional basis.

Table 1. Rules of service, Rampur.

Caste	Type of service	Rights earned through service
Khati (carpenter)	To repair agricultural tools.	1 *maund* of grain per year along with *ori* rights (2½ *sirs* of grain twice a year at each sowing season) (*41*).
Lohar (blacksmith)	To repair agricultural tools.	1 *maund* of grain per year along with *ori* rights.
Kumhar (potter)	To supply earthenware vessels and to render services of light nature at weddings.	Grains to the value of the vessels. Additional grain at the son's or daughter's marriage, according to status and capacity.
Hajjam (or Nai, barber)	To shave and cut hair; to attend to guests on their arrival and to render other services of light nature at weddings.	At each harvest as much grain as the man can lift by himself. Additional grain at the son's or daughter's marriage, according to status and capacity.
Khakrul (or Bhangi, sweeper)	To prepare cow-dung cakes; to gather sweepings, to remove dead mules and donkeys; to collect cots for extraordinary needs, and to render services at weddings.	Meals and *rabri* (*42*) twice a day; at each harvest as much grain as the man can lift by himself and also at the son's or daughter's marriage, according to status and capacity.
Camar (leather worker)	To assist in agriculture and give all kinds of light services.	One-twentieth of the produce.
	To do *begar* (compulsory labor), render ordinary service, and remove dead cattle.	One-fourth of the produce and the skins of dead cattle.
	. . .	

The full-time Jat carpenter learned his trade while he was employed at the Civil Ordnance depot at the Delhi cantonment. The others learned the trade by themselves.

Only two of the four Khati families at Rampur now carry on the traditional trade. Two Khatis are teachers; one of these supplements his income by prescribing medicines. The trade of carpentry has seen some reverses in recent years. Bullock carts formerly had wooden wheels, which used to last for a year or two, and thus provided the Khati with a dependable source of income. But now iron wheels have taken their place. Out of 33 bullock carts at Rampur, 31 have iron wheels. Plank-making has also declined. People from Rampur now prefer to have their wood cut in Delhi by a buzz-saw. The two Khati carpenters at Rampur are in debt. One of them has two employed sons who help to ease his burden. The other Khati has some part-time work as a mason and also sells milk, but he is still in debt. The decline of the carpenter's importance in this village may be seen from the fact that whereas Rampur's 1100 inhabitants are served by two or three underemployed carpenters, Wiser's village of Karimpur, with 754 inhabitants, had eight carpenter families whom Wiser described as being "constantly occupied" (*4,* p. 40).

The single Lohar (blacksmith) in Rampur is also in debt. He formerly made and repaired his *jajman*'s agricultural implements (axes, knives, and chopping tools) and during the harvest sharpened their sickles daily. In return, his *jajmans* paid him according to the schedule given in Table 1. The sale of tools was a supplementary source of income (*21*).

Technological change is not responsible for the Rampur Lohar's poverty. He does not have the money to buy tools and equipment. His difficulties seem to stem largely from having too large a family; he married twice and had three children (all daughters) by his first wife and seven children (four sons, three daughters) by the second. The marriages of his daughters put him in debt. The efforts of this man to support himself and his family show the difficulties of making ends meet in a village like Rampur. In order to pay off his debts, the Lohar decided to make some extra money by plying a horse *tonga* between Mundka and Rampur. So he borrowed 300 rupees at 15 percent interest and bought a *tonga.* But then the Lohar fell sick and had to sell the *tonga* again for 150 rupees in order to pay for his treatment. Harrassed by his creditors, the Lohar left the village after handing over the charge of his *jajmans* to a Lohar from a neighboring village. A year later, when he returned to Rampur, the Lohar found it hard to get his *jajmans* back. His debts are still mounting, for the Lohar has to support his wife, four sons, two daughters, and two daughters-in-law. His eldest son, who is 16 years old, helps him in his work, but there are no other earning members in the family.

The "mixed" nature of the *jajmani* system at Rampur is illustrated in the cases of the Chipi and Dhobi. Two generations ago there were no tailors in Rampur, but a Chipi from Gheora came from time to time to stitch clothes. Then the villagers urged him to move in and stay. He did so, and his descendants (two families) still carry on the trade (Fig. 2). The Chipis charge fixed rates in cash or kind for their work when dealing with Jat, Baniya, Khati, Lohar, or Jhinvar families. However, in the case of the Nais and Dhobis they stitch clothes free of charge in return for the latters' services. For services at weddings, the Chipis receive from 15 to 30 rupees. They are supplied with earthenware by a Kumhar, who receives so much grain per vessel; a Dhobi washes their clothes without charge; and a Bhangi does all their sweeping in exchange for one *chappatti* (*22*) a day with leftover food and the occasional present of old clothes. These families are feasted and given money at Chipi weddings —5 rupees for the Kumhar and 1 each for the Dhobi and Bhangi. A Camar is given 1 rupee at the weddings at which he assists, but there have

Table 2. *Jajmani* relationships among different castes in Rampur.

Number	Caste	Serves	Is served by
1	Brahman	2, 3, 4, 5, 6, 7, 8, 9, 10	3, 4, 6, 7, 8, 10, 11, 12
2	Jat		1, 3, 4, 6, 7, 8, 10, 11, 12
3	Baniya	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 4, 8, 10, 11, 12
4	Nai	1, 2, 3, 5, 6, 7, 8, 9, 10	1, 3, 8, 10, 11, 12
5	Chipi	1, 4, 10	1, 3, 4, 8, 10, 11, 12
6	Khati	1, 2, 3, 4	1, 3, 4, 8, 10, 11, 12
7	Lohar	1, 2, 3, 4	1, 3, 4, 8, 10, 11, 12
8	Kumhar	all	1, 4, 10, 11, 12
9	Jhinvar	(cash relationships)	(cash relationships)
10	Dhobi	all	1, 3, 4, 8, 11, 12
11	Camar	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	8, 12
12	Bhangi	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	8, 10

never been interservice relationships between the Chipis and Camars.

There are four Dhobi families in the village, but two of the family heads have turned to other occupations—agricultural labor in one case and work in an ordnance plant in the other. The two remaining Dhobi families have 21 *jajmans* in Rampur between them and from 10 to 15 in a neighboring village. They receive from 10 to 20 *sirs* of grain from each *jajman*. They also have interservice relationships with Nai, Chipi, and Kumhar families, while some Bhangis do their sweeping at the *chappatti*-per-day rate. Formerly the Dhobis depended completely upon their local *jajmans* for a living, but nowadays they have customers in Delhi as well (*23*).

Both social and technological changes have affected the position of the Nais, or barbers, in Rampur. The Nais used to cut the hair, toenails, and fingernails of their *jajmans,* while their wives shampooed the women's hair (*24*). On harvest days the Nai at Rampur shaved his *jajmans* in the fields and received one sheaf from each one. After the harvest, the Nai was invited to take a load of as many sheaves as he could carry, or else he was given from 20 *sirs* to 1 *maund* of grain.

The Nai also served as marriage go-between. A barber was often commissioned by a girl's parents to find a suitable match for the daughter. When the barber had found a boy with the right qualifications, he was sent to the youth's home along with a Brahman to offer *tika,* the ceremonial placing of a forehead mark. The Nai received *neg jog* from the boy's parents, a gift consisting of 15 rupees in cash and a double cotton sheet; the Brahman received 9 rupees and a single sheet. It was the Nai who arranged the match; the Brahman's role was secondary. The Nai was thus a man of importance in the village. According to Wiser, the Nai and his wife were among the few people at Karimpur who devoted all their time to their *jajmans.* They had no time for farming (*4,* p. 40).

In recent years the Nai's position at Rampur has changed for the worse. About 25 years ago, a Jat *panchayat* at Bawana ruled that a Nai would thenceforth receive only 6 rupees as *neg jog*. The Bawana Nais refused to accept this ruling. The Jats then decided to dispense with Nais as go-betweens and to arrange their daughters' marriages themselves. In protest, the Nais stopped shaving and cutting their *jajman*'s hair, hoping that this would lead the Jats to resume the old system. Instead, it led some of the Jats to buy razors and to shave themselves, so that when the barbers took up their trade again, they found that they had lost some of their *jajmans.*

Fig. 2. The Chipi tailors charge fixed rates for their work except in the case of the Nais and Dhobis, whose clothes they stitch free of charge in return for services.

Meanwhile, changes in women's hair styles have adversely affected the Nain, or barber's wife. Formerly, hair was set above the head, and the barber's wife, who was expert in setting it after a shampoo, received 1 *sir* of grain for dressing it. The present hair style is simpler; any woman can now arrange her own hair. Thus she is apt to shampoo and dress it herself and seldom calls in a Nain.

One of the three Nais from Rampur is now working as a barber in Delhi, the second is a teacher, and the third is a truck driver in Delhi. But they all come back to Rampur on Sundays and give shaves and haircuts to their remaining *jajmans* (Fig. 3).

Another group affected by recent *panchayat* rulings is the Kumhars (potters), of whom there are seven families at Rampur (Fig. 4). Except for one family whose head man is working in Delhi, each of the Kumhar families has a fixed number of *jajmans* to whom they supply clay vessels in exchange for specified amounts of grain (*25*). The *jajman* must take earthenware from his own Kumhar and from none other. No other Kumhar would supply such vessels in any case, unless the *jajman*'s own Kumhar lacked them. The Kumhars keep donkeys, which are needed for hauling clay from the riverbanks. These donkeys are lent out to *jajmans* when needed. This adds to the grain supplied by the latter—from 20 *sirs* to 1 *maund* of grain plus one bundle of dry fodder. A bundle of green fodder is also given from the *kharif* crop (*26*). Still more grain may be obtained from weaving, a supplementary trade engaged in by Kumhars. There are also, of course, opportunities at wed-

Fig. 3. A boy from one of the three Nai families shaves a Jat in the main street at Rampur.

dings, when *jajmans* require many clay vessels for their guests, and when the Kumhars are feasted. On these occasions they receive about 2½ rupees and about 5¼ *sirs* of grain.

A commodity much needed by the Kumhars—and by all the other villagers as well—is cow dung. Since there are only 36 trees in the whole village (each privately owned and having a fixed monetary value), wood cannot be used for burning, and cow dung is the only available fuel. Everyone needs it for that purpose, but the Kumhars need more than others, for they must have plenty of fuel to fire their pottery. Firing takes place about seven times a year, and enough cow dung must be acquired each time. The competitive scramble for cow dung among the villagers has deprived the fields of manure for fertilizer. Faced with this problem, the village *panchayat* passed a ruling 3 years ago, prohibiting its collection and imposing a fine of 5 rupees on anyone who violated the rule. Much clandestine collecting no doubt takes place, but the Kumhars have now been compelled to buy much of their fuel. For each firing, about 9 rupees' worth of cow-dung cakes must be obtained. All the Kumhars are now heavily in debt and can hardly afford the extra costs. One Kumhar owes more than 500 rupees.

The handling of cow dung is traditionally the Bhangi's job. There are ten Bhangi (sweeper) families in Rampur, about half of which have found employment in Delhi or elsewhere. The remaining families still work for their *jajmans*. Bhangis used to receive a *chappatti* a day from the latter and 20 *sirs* to 1 *maund* of grain at harvest time. They were feasted at weddings and received 1 rupee in cash, together with the leftovers of the meal. For playing drums on the occasion of the birth of a son to a *jajman*, the Bhangis were given some *gur* (*27*) and wheat; while at a Bhangi wedding the *jajman* of the family presented 1 rupee and from 2½ to 5 *sirs* of grain. These obligations are no longer adhered to with regularity. Only a few *jajmans* give grain annually nowadays. Some do so if the Bhangi helps with the harvest, but the payment is small. One Bhangi who had 16 Jat families as *jajmans* helped nine of the families at harvest time. Three families gave him only 5 *sirs* of grain; the other six gave from 15 to 20 *sirs*. The women in most of the Jat and Brahman families at Rampur now handle cow dung and make cow-dung cakes themselves (Fig. 5). However, the Bhangis are still indispensable as sweepers and removers of refuse from the home. So the *jajmani* relationship persists, although at a low rate of return for the Bhangis.

All the Bhangis at Rampur are heavily in debt and owe money to the Jats. In the past, they used to borrow money from their *jajmans*, either interest-free or at very low rates, but now they must pay from 12 to 18 percent a year. Moreover, it is not easy to get loans. If a Bhangi approaches one of the Jats for this purpose, he may be told sarcastically to seek help from the Congress Party or from one of the politicians the Bhangi voted for on election day.

It is not surprising that the Bhangis have become hostile toward the Jats, as have the Camars, who will be discussed in a subsequent paragraph. This hostility has been fanned by some restrictive measures that have cut down the Bhangis' sources of income. The Bhangis formerly kept poultry. But the Jats were annoyed when the chickens made tracks over their freshly made cow-dung cakes, and they expressed their displeasure by manhandling some of the Bhangis. No chickens are kept nowadays. The Bhangis also used to keep pigs. But the pigs, like the chickens, were apt to stray and spoil somebody's crops. The Jats told the Bhangis that the pigs would not be allowed to drink water at the village pond. Fines were imposed if pigs were found drinking there. The Bhangis therefore had to sell their pigs or else take them away to relatives in other villages. The loss of chickens and pigs meant a loss of supplementary income—not a small matter to people so deeply in debt (*28*).

The greatest break with the *jajmani* system at Rampur has come from the Camars, traditionally the leather workers of India. They formerly removed their *jajman*'s dead cattle, repaired their shoes and other leather objects, and helped them in agricultural work. George Briggs, writing as long

ago as 1920, affirmed that the special role of the Camar in India's rural villages was doomed: "With the rise of the large-scale tanning industry in certain large centres, the village tanner's enterprise is being reduced to smaller dimensions. There is little likelihood that the rural industry will survive. In this connection it is interesting to note that during the decade ending in 1911 there was a very marked decrease (36.9 per cent.) in the number engaged in tanning, currying, dressing, and dyeing leather. At the same time the Chamar population increased. Furthermore one of the results of the war has been a very great advance in large-scale tanning. The demand for village tanned leather is gradually being reduced to that of water-buckets and thongs. The former will be supplied more and more from chrome tanned leather, which is not a rural product at all, and finally, cheaper fabrics made from vegetable fibres will supplant leather for irrigation purposes. Slowly factory tanned leather will supplant village tanned leather in the village shoemaking industry" (*29*).

However, leather-working is only one of the Camar's traditional tasks. Ibbetson has described some of their duties in the Karnal tract, not far from Rampur: "The *Chamárs* are the coolies of the tract. They cut grass, carry wood, put up tents, carry bundles, act as watchmen and the like for officials; and this work is shared by *all* the *Chamárs* in the the village. They also plaster the houses with mud when needed. They take the skins of all animals which die in the village except those which die on Saturday or Sunday, or the first which dies of cattle plague. They generally give one pair of boots per ox and two pairs per buffalo skin so taken to the owner" (*30*).

Table 3 gives some of the traditional obligations and payments for the Camars at Rampur.

Camars were formerly required to perform *begar*, including compulsory service for government officials who visited the village. In general, their position has always been a very low one, but recently they have been making efforts to raise their status and have discontinued some of their traditional *jajmani* obligations and services. They have developed mutual feelings of hostility with the Jats in consequence. During the past 20 years or so, the Camars seem to have been losing some of the sense of inferiority associated with their low caste status and untouchability. This has partly been due to the efforts of organizations such as the Arya Samaj, the Congress Party, and some of the other political parties in India. The Arya Samaj, a Hindu religious reform movement, has long campaigned against caste restrictions in this area, apparently with some effect. They held a conference in Rampur in 1910 at which some non-Brahman groups, principally the Jats, were persuaded to wear the sacred thread that was formerly reserved for the use of Brahmans. The Jats were urged not to feast Brahmans at ceremonial occasions, for this custom merely developed greediness in the latter caste. Besides, the speakers pointed out, village Brahmans are mostly illiterate, Brahmans only by birth, who have no real knowledge of the Vedas. In 1933, a second Arya Samaj conference was held at Rampur, this time directed against untouchability. The speakers told the Camars in the audience that unpaid *begar* service had no legal basis and that they should refuse to perform it. The speakers promised

Fig. 4. The potter has a fixed number of families whom he supplies with clay vessels.

Fig. 5. Even Jat and Brahman girls make cow-dung cakes. The structure behind these girls is made of such cakes.

the Camars assistance if they got into trouble for refusing *begar* service. As a result, the Camars stopped rendering *begar*.

The Camars who carried away the dead animals of their *jajmans* used to eat the flesh of these animals. When previous attempts had been made to remove untouchability, the Jats had objected on the grounds that the Camars ate carrion. At the 1933 conference, the Arya Samaj speakers exhorted the Camars to give up eating the flesh of dead animals and to keep themselves and their homes clean so that untouchability could be removed. The Camars took a vow to do so. Most of the Jats at the conference then drank water at the hands of the Camars. These Jats were subsequently boycotted by the Brahmans for this violation of caste rules.

Despite this gesture on the part of some of the Jats, tensions developed between the Jats and the Camars. These had been manifest before the 1933 conference. In 1926 the Camars refused to pay the traditional house tax (*kudhi-tarif*) of 2 rupees per year to the Jats. The Camars of the few surrounding villages raised 450 rupees, a tremendous sum at that time, and took the case to the court. However, the other non-Jats of the village, still dependent upon the Jats as their *kamins*, did not support the Camars. All the Jat factions united in opposing the Camars. The case dragged on for 2 years, and the Jats finally won. However, the Camars still refused to pay the tax, and a court decree was obtained by the Jats for the auction of the Camars' property. Both of the *lambardars* (headmen) of the village along with other Jats led by the court-appointed officer, went to the house of the leader of the Camars and forcibly confiscated some brass vessels, *ghi*, and cotton, all of which were taken to a Jat's house, where they were held until the tax was paid.

A few years later the Camars and Jats fought another court case. This time the Camars brought criminal proceedings against some Jats who had beaten them for carrying meat in their pots. Then, in 1938, the house tax question came up again. During the preceding 10 years, the Jats had failed to collect the house tax, which they now demanded in lump sum. When the Camars pleaded inability to pay, the taxes during this 10-year period were forgiven. But the Camars went on to pay taxes from 1938 to 1947. There were three other court cases between the Camars and Jats from 1930 to 1947. In one case, the Jats asked the Camars to assign a man each day to keep a day watch to guard Jat harvests against animals and thieves. When the Camars refused, the Jats took the case to court. A compromise was reached in which the Camars agreed to a night watch rather than a day watch. The Camars interpreted this as a victory, and they

Table 3. Services rendered and payments received by Camars, Rampur.

Occasion	Services rendered	Payment received
Boy's marriage	1) Felling trees, cutting wood for fuel. 2) Providing a watch at the house after the wedding party has left. 3) Accompanying the wedding party; attending to the bullocks at the bride's home.	1) Meals when cutting wood. 2) 1 rupee at departure of the wedding party. 3) 1 rupee at departure of the wedding party from the bride's home. 4) 1 rupee and some grain (usually 5 to 10 *sirs* of wheat.
Girl's marriage	1) Cutting wood for fuel. 2) Assistance in reception of wedding party. 3) Feeding their bullocks. 4) Keeping watch where party camps. 5) Making repairs in the house.	1) Meals for the whole family four times during the 3-day stay. 2) 1 rupee at wedding party's departure. 3) 1 rupee, wheat (usually 5 to 10 *sirs*), and clothes after the wedding.
Ordinary service	1) Work without payment for officials (*begar*). 2) Repairs of *jajman's* shoes. 3) Work in extraordinary situations (illness or death, and so forth). 4) Help in harvesting. 5) Removal of dead cattle.	1) Meals on days of work for *jajman*. 2) 1 *sir* of grain at harvest time. 3) Grain left over on the threshing floor. 4) Animal carcases taken. 5) One-fortieth of the grain produce (minimum 2 to 5 maunds.)
Extraordinary service	1) Full time work in harvesting *rabi* crop. 2) Full time work in harvesting *kharif* crop.	1) One-twentieth of the produce. 2) One-tenth of the produce if 100 *maunds* or over; more if the *kharif* crop is less. 3) Meals given on work days.

became more aggressive, severing all their occupational and ceremonial relations with the Jats, including the burial of dead animals. After about 6 months, however, they resumed the removal of dead animals and maintained this service until the time of Indian independence. During World War II, many Camars from Rampur were employed in a nearby ordnance depot and in other military jobs, which gave them an opportunity to take an independent stand.

With the coming of independence, the position of the Camars was strengthened both legally and ideologically. Now the Jats could no longer enforce the provisions of the *wajib-ul-arz*, which specified the traditional village duties. The Camars stopped the payment of the house tax and the handling of dead animals. However, with the more limited opportunities for employment after the war, the Camars once again became dependent on the Jats. This put them in a difficult position *vis-à-vis* the Jats because they had openly opposed the latter in the *panchayat* and had supported the Congress Party candidate, who was opposed by most of the Jats (*31*, p. 68 ff.)

Giving up the practice of removing dead animals was a gradual process. For a while, the Camars removed only those animals that had died a lingering death from badly smelling wounds. The Jats disposed of other carcasses by burial. This violated provisions laid down in the *wajib-ul-arz*. Previously, when a Jat had buried a bullock, the Camars had reported the matter to the police, who then had the carcasses dug up and turned over to them. If the skin were decomposed, the Jat was made to pay the cost of the skin to his Camar.

The burial of animals by the Jats, however, was not without precedent. A mass burial of animals used to take place at *aikta* ceremonies, when there was a cattle epidemic. On these occasions, a curer was brought to the village, and all the livestock was brought together in one place. The curer performed some ritual actions and burned incense near the animals, all of which were then driven beneath a sacred stick. Ganges water was sprinkled about in all the houses. No outsiders were admitted into the village on this day, nor could any of the villagers leave. Various taboos prevailed; no iron utensils were used, flour was not milled, *chappattis* were not cooked, and houses remained unswept. The ceremony began on a Saturday and lasted until Sunday evening. At these times the Jats used to seek the Camars' permission to kill and bury the cattle, but this permission was readily granted, for the Camars also wanted the epidemic to end. Gradually, however, the Jats began to perpetuate the practice of burying dead cattle.

In 1934–35 the Camars temporarily gave up removing dead animals, partly because of objections raised by a doctor, who claimed that they were skinned too near the villagers' homes. Two years later, when a different place was set aside for the skinning, the removal of dead animals was resumed rather half-heartedly by the Camars. In 1947, on the eve of Indian independence, the Camars at Rampur gave up the practice altogether and have not resumed it since.

After the 1933 Arya Samaj conference, when the Camars gave up rendering *begar* service, the Jats began to cut down on the amounts of grain given them, claiming that the stipulations in the *wajib-ul-arz* had been violated by the Camars. Some of the latter say that this was a mere excuse on the part of the Jats. The main factor, according to them, was the increased price of grain.

Another factor must have been the increasing fragmentation of land. When the size of land holdings was large, and when they could not be managed without outside help, the traditional assistance of the Camars was sought and welcomed by the Jats; but as land holdings became smaller and families larger, and as pressure on the land brought about further fragmentation, the assistance of the Camars became less crucial. This was, of course, a gradual process; it did not happen overnight (*32*).

Technologic changes have also had their effect. A mechanical iron cane crusher has now supplanted the old wooden type of crusher and obviated the large work crew that managed the old machine. Chaff cutting machines have supplanted the old tools used for that purpose (Fig. 6). The Jat land-owners are now less dependent on Camars in these areas.

Meanwhile, the Camars have been trying to raise their socioreligious status by following higher-caste practices and giving up the consumption of dead animal flesh. Their ties to their *jajmans* have weakened. Gradually they have given up repairing the latters' shoes, another of their traditional *jajmani* obligations.

The opportunity to enter schools is now a new channel to higher status. None of the older Camars at Rampur can read or write, but 85 percent of their boys aged 6 to 15 are attending school. In Kanjhawla High School, the untouchables and higher-caste boys eat together, while in the local school young Camars and Jats sit side by side. Since 1949 a Camar has been elected to the newly constituted intervillage council of four villages.

During World War II new kinds of employment were made available to the Camars, and some went to Delhi to work. Although there has been a postwar contraction of employment, four of the 21

Fig. 6. The mechanical chaff cutter has made the Jat farmers less dependent upon the help of the lower caste Camars.

Camar families at Rampur have found employment outside the village. Two work as agricultural laborers for 1 or 2 months a year at daily wages. Some work as occasional day laborers. Three Camar families do weaving, four have taken up a guava garden on a contract basis, and four have started vegetable growing. Some raise cattle to supplement their income. Only two Camars in the village are shoemakers.

One of the Camars was asked why the other Camars did not also make shoes to supplement their income. He answered that capital is needed to buy cured hides, which cost from 50 to 60 rupees. Even if they somehow managed to buy a hide, they would have to sell shoes on credit and in most cases get only grain in return. The problem of getting funds for another hide would remain as before. The informant was questioned as follows:

"How did you manage it before?"

"We used to remove the dead cattle and tan the hides ourselves."

"Couldn't that system be revived?"

"Most of us don't want to skin leather any more."

"But couldn't you find just one man who would agree to do it for the others?"

"Well—that's a good idea. But all the other villagers would have to agree."

As it is, under the present system, all the hides at Rampur are going to waste, buried in the earth year by year. If cured hides cost from 50 to 60 rupees, this represents an enormous loss to the villagers.

It is not only low-caste groups that have abandoned their *jajmani* obligations at Rampur. The Brahmans have also done so. They formerly used to officiate at marriages and other ceremonies at the homes of their *jajmans,* at which times they received from 20 *sirs* to 2 *maunds* of grain and fodder. Every day during the cane-crushing season, a farmer would set aside from 1½ to 2 *sirs* of *gur* for his Brahman. Brahmans had traditional roles to play at festivals such as Kanagat and Makar Sankrant, at which they were feasted, and also in the event of a Kaj, a celebration in honor of the dead. The Arya Samaj, as has been noted, has expressed opposition to the feasting of Brahmans, and the Jats have been influenced by this point of view. Partly for this reason—perhaps also for the sake of economy—they have stopped feasting Brahmans. A Kaj has not been given for several years, and at festival times the Brahmans are seldom fed. (Cows or young girls are sometimes fed instead.) The Rampur Brahmans, for their part, claim that they regard the acceptance of food and charity as demeaning and that they prefer not to accept it. The Brahmans no longer settle marriage agreements, cook food at weddings, or carry on priestly functions. Four of the Rampur Brahmans are now cultivators, although only two make this their sole means of support. One of the Brahmans is a tailor, another sells milk.

There is one Baniya (merchant) family in the village which owns a shop. According to Wiser, the Vaisyas, who are absent in Karimpur, do not form an essential part of the Hindu *jajmani* system. This grouping would include the Baniya. Wiser quotes Sir Henry Maine to the effect that "the grain dealer (Vaisya) is never a hereditary trader incorporated with the village group" (*4,* p. 143). The villagers at Rampur, however, speak of the Baniya as if he took part in the *jajmani* system. He has *jajmani*-type relationships, at least, with the Brahman families in Rampur and is served by Nais, Dhobis, Kumhars, Camars, and Bhangis. Besides selling grain and other commodities, the Baniya enters certain records in an account book for the benefit of some Rampur families. The gift of money (*neota*) presented at a wedding is recorded in this book, for the same sum must be paid back when there is a marriage in the donor's household. The Baniya receives 2 rupees for this service. He also keeps records, without charge, of loans made by one man to another. The Baniya was formerly paid for weighing grain, but most people weigh the grain themselves nowadays, and the Baniya has lost this source of income. According to Ibbetson, the Baniyas in the Karnal tract give a ball of *gur* on the day after Holi and some parched rice or sweets on Divali to the proprietors "in recognition

of the subordinate position which they occupy in the village" (*30*, p. 118).

The following sums up the present situation of the *jajmani* system: The system is still functioning in Rampur, a village close to Delhi, the nation's capital. Despite modern improvements, technological changes, India's 5-year plans, the influence of reformist movements, and political ideologies, the system is not yet dead. However, changes are taking place. The Camars have stopped fulfilling some of their *jajmani* obligations toward the Jats, who have reciprocated in turn. There are also indications of tension between the Jats and the Bhangis, although the latter continue to serve their *jajmans*. The Brahmans have lost their priestly functions. The Dhobis, who formerly depended completely upon their local *jajmans*, now have customers in Delhi as well. The Khatis and the Lohar are abandoning their traditional trades. The Nais have lost their roles as marriage go-betweens as well as some of their opportunities as barbers.

Most of the lower caste villagers—and many of the Jats—are in debt. Some have been led to change their occupations and have gone to Delhi to look for work. Technological changes and the increasing land fragmentation have reduced the need for help in agriculture among the Jat families. Meanwhile, the Arya Samaj and some of the political parties have preached, with some effect, against caste restrictions. All these factors have led to a loosening of *jajmani* ties and obligations.

Discussion

In a chapter in which he weighed the advantages and disadvantages of the *jajmani* system, Wiser drew an essentially benevolent picture of how it provided "peace and contentment" for the villagers (*4*, p. 187). The account by Opler and Singh has a similar emphasis: "Not only does everyone have some place within the Hindu system, but it is significant that every group, from the Brahman to the Chamar caste, has been somehow integrated into the social and ceremonial round of the community and has been given some opportunity to feel indispensable and proud" (*6*, p. 496; *33*).

Our picture of Rampur, however, leads to a quite different assessment, for it seems evident that the relationship between *jajman* and *kamin* lends itself to the exploitation of the latter. Land ownership is the basis of power in Rampur. All the village land, including the house sites, is owned by the Jats; the other castes are thus living there more or less at the sufferance of the Jats. It was this crucial relationship to the land, with the attendant power of eviction, that made it possible for the Jats to exact *begar* service from the Camars in the past and still enables them to dominate the other caste groups. Moreover, some of the latter, such as the Bhangis, are deeply in debt to their *jajmans*. This gives the Jats an additional hold over their *kamins*.

Although Wiser's definition of the *jajmani* system and his theoretical discussion of it stress the element of reciprocity, most of his own data point to the asymmetrical nature of the power relationship. The same exploitative situation can be shown to exist in other areas where the *jajmani* system is found. Writing of a village near Lucknow, Majumdar and his colleagues write that the higher caste people always try to humiliate the lower castes. "The Thakurs dictate the most ruthless terms to the Chamars who take their fields as share croppers" (*34*). Reddy notes that a Lohar receives much less for his work from his Thakur *jajmans* than he gets from other castes (*7*, p. 137). Reddy also mentions that Lohars get beaten by their *jajmans* for delinquencies in their obligations (*7*, pp. 139–140). Even Wiser, despite his favorable assessment, showed awareness of the harsh realities of the power relationship in *The Hindu Jajmani System* (*4*). But this awareness was given a much sharper expression in the book *Behind Mud Walls*, which was written in collaboration with his wife Charlotte Viall Wiser:

"The leaders of our village are so sure of their power that they make no effort to display it. The casual visitor finds little to distinguish them from other farmers. . . . And yet when one of them appears among men of serving caste, the latter express respect and fear in every guarded word and gesture. The serving ones have learned that as long as their subservience is unquestioned, the hand which directs them rests lightly. But let there be any move toward independence or even indifference among them, and the paternal touch becomes a strangle-hold . . . in every detail of life have the leaders bound the villagers to themselves. Their favour may bring about a man's prosperity and their disfavour may cause him to fail, or may make life so unbearable for him that he will leave the village" (*35*, pp. 18–19). It is also evident from Wiser's data that the upper castes receive much more than the lower castes in goods and services (*4*, pp. 70–71; *18*, p. 98).

That the ownership of land, including house sites, is the crucial factor, appears in other areas as well. "In the good old days," writes Darling of the Punjab, "village servants were in complete subjection to their 'masters,' and this is still largely the case in the feudal north and west. There the fear of ejection from the village is a yoke which keeps the head bowed, and only those who own their

own house and courtyard dare assert themselves" (*13*, p. 272). An informant told Gittel Steed: "You have seen the whole Bakrana, every house probably. Have you seen any house that can be called a good house? This is because everyone is frightened of being driven out at any time. No one wants to build a good house here" (*12*). "That the *zemindar* is all-powerful in such places need hardly be stressed," writes Mohinder Singh. "The threat of demolishing a man's dwelling or ejecting him therefrom are powerful weapons in his hand for extorting *begar*. Till recently the cultivators did not have any rights in their house sites" (*35a*, p. 193).

While the landowners are generally of higher caste in Indian villages, it is their position as landowners, rather than caste membership per se, that gives them status and power. In Karimpur, where the Brahmans are the landowners, the traditional caste hierarchy obtains. But in Rampur the Jats own the land, and the Brahmans are subservient to them. Majumdar and his colleagues present a similar picture in their description of the village near Lucknow: "The respect which the Brahmins enjoy is merely conventional; in daily life, however, the Brahmins are treated on an equal footing with the other castes. . . . The Thakurs are the most influential group of people in the village because they are economically better off. They own most of the agricultural land in the village. They are the landlords who give employment to the other caste-people. The various other castes serve the Thakurs as their dependents" (*34*, p. 193). Opler and Singh also report that in Madhopur the Brahmans, "in spite of their top position in the orthodox social scale, are not influential. The reason is that they are economically dependent on others" (*36*, p. 180). In Madhopur it is the Thakurs who own the land, more than 82 percent of it, and it is they who form the dominant caste, as in the study just cited. In another village described by Opler and Singh, a lower caste Ahir is headman of the village and leader of the village *panchayat*. He owns 50 acres—"the only villager who has actual ownership of any substantial portion of village land" (*36*, p. 187). In an early work by Russell and Hira Lal, an area is discussed where Kunbis have higher-than-usual status. "The only reasonable explanation of this rise in status appears to be that the Kunbi has taken possession of the land and has obtained the rank which from time immemorial belongs to the hereditary cultivator as a member and citizen of the village community" (*37*).

Since the passing of *zamindari* abolition bills, the key power of landowners may have been curtailed in certain areas. Majumdar and his colleagues, for example, report that in the village they studied near Lucknow, where *zamindari* abolition has taken place, Camars now refuse to perform *begar*, while the barbers refuse to draw water for the Thakurs and will not wash their utensils or remove their leaf-plates any more (*34*, pp. 191–192). However, the occurrence of *begar* since Indian independence has been noted in some areas—by Gittel Steed (*12*), for example, and by Shridhar Misra (*38*).

A qualification may be suggested, that while a landowner may have both tenants and *kamins*, the two groups need not be identical. He may have *kamins* who are not his tenants. This point is made by Opler and Singh, who also note that when there are disputes between Thakurs, the tenants align themselves with their landlords (*6*, p. 495). Perhaps a more crucial consideration, however, is that the Thakurs in Senapur, like the Jats in Rampur, form a caste group that may (despite factional cleavages and differences in wealth) join ranks in solidarity *vis-à-vis* the lower castes in crucial issues. All the Jat factions in Rampur, for example, united in opposing the Camars over the house-tax matter.

The lower castes, theoretically at least, have a potential retaliatory weapon in the boycott, or withdrawal of their services. Thus, when the Nais of Rampur were informed of a decision by the Jats to reduce the *neg jog* paid at weddings, they stopped shaving and cutting their *jajmans*' hair in protest. But the sequel is instructive: The Jats retaliated by buying razors and shaving themselves. This shows that such protests may prove to be self-defeating. It also indicates that the *jajmani* system may be disrupted by action of either the *jajmans* or the *kamins*, or by the cumulative effect of both.

As the *jajmani* system declines, a great deal of tension is bound to develop between the landed and the landless, between the upper and lower castes, particularly since the system's decline is concomitant with a great increase in population and a decrease in the size of landholdings. Although the dominant position of the Jats is not yet in jeopardy in Rampur, their influence over the lower castes has been much reduced, and the demands of the lower castes have increased. It would therefore seem that the *jajmani* system contains some explosive potentialities and that, as the system continues to weaken, we may expect to see a heightening of the conflict between the dominant and subordinate castes in villages such as Rampur.

Meanwhile, despite the weakening of the *jajmani* system and the inroads of a money economy in Rampur, the social aspects of the caste system have changed very little. The rules of endogamy are not questioned (*39*). Despite the influence of the Arya Samaj, the traditional caste rules governing inter-

dining and the taking of water still prevail. The Jats will not share their hookahs with Camars or Bhangis or sit on the same string-cots with them (see also Cohn, *31*, p. 61). When community project speakers address the people of Rampur in would-be democratic assemblages, the Camars remain on the outskirts of the crowd. Patterns of hierarchy and social distance persist, and the psychology of caste still permeates interpersonal relationships.

In some ways caste identifications have even strengthened in Rampur. Among the Jats the emphasis on caste loyalty may represent a defensive reaction to the weakening of the *jajmani* system, while among the Camars it signifies a united stand *vis-à-vis* the higher caste landowners. A similar point, on a broader scale, has been made by Srinavas, who discusses the ways in which the modern political system, including universal adult franchise, has strengthened caste.

"The principle of caste," writes Srinavas, "is so firmly entrenched in our political and social life that everyone including the leaders have accepted tacitly the principle that, in the provincial cabinets at any rate, each major caste should have a minister (And this principle has travelled from our provincial capitals back to our village *panchayats* —nowadays the latter give representation on the *panchayat* to each caste including Harijans). In the first popular cabinet in Mysore State, headed by Shri K. C. Reddy, not only were the ministers chosen on a caste basis, but each had a secretary from his own sub-sub-sub caste. And today in Mysore this principle is followed not only in every appointment, but also in the allotment of seats in schools and colleges. . . . voting is on a caste basis, and voters do not understand that it is immoral to demand that the elected minister help his caste-folk and village folk. . . . no explanation of provincial politics in any part of India is possible without reference to caste. . . . In general, it may be said that the last hundred years have seen a great increase in caste solidarity and the concomitant decrease of a sense of interdependence between the different castes living in a region" (*40*).

While this may perhaps be overstating the case, it is a necessary corrective to the more widely held assumption that caste is crumbling rapidly. The decline of the *jajmani* system, then, will not necessarily be followed by an automatic or speedy disintegration of the caste system. Instead, caste may continue to take on new functions and manifestations.

References and Notes

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1. A caste is an endogamous social unit, membership in which is determined by birth; it is often associated with a particular occupation and with restrictions about the acceptance of food and water from other caste groups. Castes tend to be ranked, with the Brahmans being traditionally assigned the highest status and "untouchable" castes such as the Bhangi (sweepers) the lowest.
2. W. H. Wiser, *The Hindu Jajmani System* (Lucknow 1936). There have been a few other works dealing with the relationship between caste and economics, notably S. S. Nehru's *Caste and Credit in the Rural Area* (Longmans Green, Calcutta, 1932). Kumar Goshal has emphasized the economic basis for the caste system in the following words: "Hindu reformers failed to make any headway against the caste system because it was rooted in the economy of India, and only a change in that economy could bring about a change in the social structure. The economic system was stabilized at a low level, based upon more or less self-sufficient village communities which combined agriculture and handicrafts. Production was on a small scale, and for consumption rather than exchange. Everything moved in narrow, well-worn grooves fixed by custom. It was a pre-capitalist economic system, whose static quality could have been altered only by an expanding dynamic market for exchange of commodities. As long as this was lacking, the social relationships of the people could not possibly be altered." [Kumar Goshal, *The People of India* (Sheridan House, New York, 1944, p. 59)]. O. C. Cox was also aware of the importance of economic factors, as the following quotation shows: "The caste structure is fundamentally a labor structure, a system of interrelated services originating in specialized groups and traditionalized in a religious matrix." Cox quotes Pramathanath Bannerjea as follows: "The chief economic significance of the system is that it fixes absolutely the supply of any kind of labor. The scope given for the play of competition thus becomes limited, and consequently the law of demand and supply is rendered inoperative or oppressive in its operation. When any change takes place in the economic world, labor is unable to adjust itself. . . . Wages and prices have very often to be regulated by custom or some artificial means." [O. C. Cox, *Caste, Class, and Race* (Doubleday, New York, 1948), pp. 62, 67]. An awareness of the relationship between caste and economy, however, seems to be missing in even such a standard book as J. H. Hutton's *Caste in India* (Oxford Univ. Press), in the revised edition of which (1951) there is no reference to the *jajmani* system or to Wiser's work.
3. Webster's *Dictionary* (1950) defines *jajman* as "a person by whom a Brahman is hired to perform religious services; hence, a patron; client." The word derives from the Sanskrit *yajamana,* the present participle of *yaj,* to sacrifice. The term ultimately came to be used for anyone standing in the relationship of employer.

4. W. H. Wiser, *The Hindu Jajmani System* (Lucknow, 1936).
5. See E. Eames, "Some aspects of urban migration from a village in north central India," *Eastern Anthropol.* **8**, 19 (1954).
6. M. Opler and R. D. Singh, "The division of labor in an Indian village," in *A Reader in General Anthropology,* C. S. Coon, Ed. (Holt, New York, 1948), pp. 464–496.

7. N. S. Reddy, "Functional relations of Lohars in a north Indian village," *Eastern Anthropol.* **8**, 129 (1955).
8. E. J. Miller, "Village structure in North Kerala," *Economic Weekly*, Bombay, 9 Feb. 1952, pp. 159–164.
9. M. N. Srinavas, "The social system of a Mysore village," in *Village India*, M. Marriott, Ed. American Anthropological Association, 1955, Memoir 83, pp. 1–35; A. R. Beals, "Interplay among factors of change in a Mysore village," *ibid.*, pp. 78–101.
10. E. K. Gough, "The social structure of a Tanjore village," *ibid.*, pp. 36–52.
11. S. C. Dube, *Indian Village* (Cornell Univ. Press, Ithaca, 1955).
12. G. Steed, lecture notes, hectographed.
13. M. L. Darling, *Wisdom and Waste in the Punjab Village* (Oxford Univ. Press, London, 1934).
14. According to M. Singh [*The Depressed Classes* (Hind Kitabs, Bombay, 1947)] Bhangis (sweepers) can sell their *jajmani* rights for as much as 200 rupees.
15. Hazari, *An Indian Outcaste* (Bannisdale Press, London, 1951), pp. 12–13.
16. S. S. Nehru, *Caste and Credit in the Rural Area* (Longmans Green, Calcutta, 1932).
17. Rampur is 27 miles off the main Delhi-Fazilka road with which it is connected by a cart track. The village can also be reached from the Delhi-Ferozpur railway line. Gheora and Nangloi, the two nearest railway stations, are at a distance of a few miles from the village.
18. S. Misra gives a list of payments at marriage and sacred-thread ceremonies to different "village servants" in a village in U.P.: "Earnings of village servants in U.P.," *Eastern Anthropol.* **5**, 98 (1952).
19. For a fuller list of items made by village carpenters, see Wiser (*4*, pp. 35–36).
20. A rupee is worth about 21 cents.
21. Reddy gives some details about the Lohar's work and payments in eastern Uttar Pradesh (*7*, p. 136). The work includes carpentry, which in Rampur would be done by the carpenter. "The carpentry that is needed in the construction of houses, major repairs of mechanical chaff-cutter and sugar-cane press and making of carts are outside the Jajmani system. Small repairs in the house or minor adjustments of the chaff-cutter and sugar-cane press are generally done by one's own Lohar *Parjan*. If the work takes less than an hour, the Lohar does not get any payment. If such work, however, extends over a few hours, he gets a nominal payment in grain that is sufficient for one meal. If the work outside the Jajmani system takes a whole day or more, he gets fixed wages."
22. *Chappatti*: a wheat cake made of unleavened flour.
23. For a good account of a Dhobi's work in a south Indian village, written at the end of the 19th century, see T. B. Pandian, *Indian Village Folk* (London, 1898), p. 23 ff.
24. "Shaving under the arms weekly, finger-nail cutting weekly, and toe-nail cutting fortnightly, are added to the tonsorial duties of the barber. Ordinarily hair is cut monthly except when his clients have their heads shaved for religious purposes or through choice. . . . At the time of a wedding he not only shaves the men in his own jajman's household, but he also shaves the guests from other villages—relatives of his jajmans"—Wiser (*4*, pp. 38–39).
25. "The Kumhar makes for village use, large round-bellied water jars, various types of jars used for milking, boiling, churning, etc., lids for water and milk jars, funnel-shaped tobacco pipe bowls, saucers which are used for the mustard oil lights, saucers for serving liquid foods at weddings, cups without handles, jars for storing grain, smaller jars for preserving spices and chutneys, feeding jars for cattle, and various other types of clay vessels"—Wiser (*4*, pp. 45–46).
26. *Kharif*: the rainy season and the crops planted during it.
27. *Gur*: a crude brown sugar which includes molasses.
28. According to Mukerjee, however, some low caste groups have deliberately abandoned the raising of pigs and poultry in order to raise their status. See R. Mukerjee *et al.* "Intercaste tensions" (Univ. of Lucknow, mimeographed, 1951), p. 14.
29. G. Briggs, *The Chamars* (Oxford Univ. Press, London, 1920), p. 227. The increasing use of Persian wells has cut down on the demand for leather buckets.
30. D. C. J. Ibbetson, *Report on the Revision of Settlement of the Panipat Tahsil and Karnal Parganah of the Karnal District, 1872–1880* (Pioneer Press, Allahabad, 1883), pp. 116–117.
31. For a similar dilemma, see "The changing status of a depressed caste," based on reports by Bernard S. Cohn, in *Village India*, M. Marriott, Ed. (American Anthropological Association, Memoir 83, 1955).
32. Some aspects of the conflict between the Jats and Camars at Rampur have been dealt with in O. Lewis, "Group dynamics in a North-Indian village: A study in factions," *Economic Weekly*, Bombay 6, pp. 423–425, 445–451, 477–482, 501–506 (1954). A discussion of land tenure, population pressures, and related economic problems appears in O. Lewis, "Aspects of land tenure and economics in a North-Indian village," in *Economic Development and Cultural Change* **4**, No. 3, 279–302 (1956).
33. The institution of caste has, of course, been lauded and attacked by various writers both in India and the West. H. Maine described it as "the most disastrous and blighting of all institutions," and R. Tagore called it "a gigantic system of cold-blooded repression." But Abbé Dubois, who was often critical of Indian customs, referred to caste as "the happiest effort of Hindu legislation." Gandhi expressed both points of view at different times. "Historically speaking," he once averred, "caste may be regarded as man's experiment or social adjustment in the laboratory of Indian society. If we can prove it to be a success, it can be offered to the world as a leaven and as the best remedy against heartless competition and social disintegration born of avarice and greed." But Gandhi also wrote, "Caste has nothing to do with religion. It is harmful both to spiritual and national growth." These quotations from Gandhi come from N. K. Bose, Ed., *Selections from Gandhi* (Navajivan, Ahmedabad), pp. 232, 234. That of Dubois is from J. A. Dubois, *Hindu Manners, Customs, and Ceremonies*, translated by H. K. Beauchamp (Clarendon Press, Oxford, 1947), p. 28. The quotations from Maine and Tagore are drawn from L. S. S. O'Malley, *Indian Caste Customs* (Cambridge University Press, Cambridge, 1932) p. vii.
34. D. N. Majumdar *et al.*, "Intercaste relations in Gohanakallan, a village near Lucknow," *Eastern Anthropol.* **8**, 211 (1955).
35. C. V. Wiser and W. H. Wiser, *Behind Mud Walls* (Agricultural Missions, New York, 1951); see also Cohn (*31*, p. 61).
35*a*. M. Singh, *The Depressed Classes* (Hind Kitabs, Bombay, 1947), p. 35.
36. M. E. Opler and R. D. Singh, "Two villages of eastern Uttar Pradesh," *Am. Anthropol.* **54**, 180 (1952).
37. R. V. Russell and R. B. Hira Lal, *The Tribes and Castes of the Central Provinces of India* (London, 1916), vol. 4, p. 22.
38. S. Misra, "Caste survey in two modal villages with stereotyped discriminations," in *"Intercaste tensions"* (*28*, p. 58). In a rural survey conducted by

Misra, 11 out of 40 persons examined on the subject of *begar* admitted that they had to do *begar* at the instance of *zamindars*. Such *begar* usually takes the form of ploughing without payment once a year. For some striking descriptions of *begar* during the period of British rule, see G. Emerson, *Voiceless India* (John Day, New York, 1944), pp. 28, 173.

39. Caste endogamy is still the rule even in large cities, as was shown in a study by N. P. Gist, "Caste differentials in South India," *Am. Sociol. Rev.* **19**, 138 (1954). "Out of some two thousand married Hindu household heads who supplied information," writes Gist, "only nine stated that they and their wives belong to different castes." These surveys were made in Mysore and Bangalore.

40. M. N. Srinavas, "Castes: Can they exist in India of tomorrow?" *Economic Weekly*, Bombay, 15 Oct. 1955, pp. 1231–1232. For some other discussions of the new functions of castes, see D. R. Gadgil, *Poona, A Socio-Economic Survey* (Gokhale Institute, Poona, 1952), part 2, p. 187; B. Ryan, *Caste in Modern Ceylon* (Rutgers Univ. Press, New Brunswick, N.J., 1953), p. 321; K. Davis, *The Population of India and Pakistan* (Princeton Univ. Press, Princeton, N.J.), p. 175.

41. *Maund*: a unit of weight containing 40 *sirs*; *sir*: a weight of about 2 pounds.

42. *Rabri*: a preparation made from churned curd and flour.

I cannot condemn a man for ignorance, but behold him with as much pity as I do Lazarus. It is no greater charity to cloath his body, than apparel the nakedness of his Soul. It is an honourable object to see the reasons of other men wear our liveries, and their borrowed understandings do homage to the bounty of ours: it is the cheapest way of beneficence, and, like the natural charity of the Sun, illuminates another without obscuring itself.... To this (as calling myself a Scholar), I am obliged by the duty of my condition: I make not my head a grave, but a treasure of knowledge; I intend no monopoly, but a community, in learning; I study not for my own sake only, but for theirs that study not for themselves. I envy no man that knows more than myself, but pity them that know less. . . . In all disputes, so much as there is of passion, so much as there is of nothing to the purpose; for then Reason, like a bad Hound, spends upon a false Scent, and forsakes the question first started. . . . Scholars are men of Peace, they bear no Arms, but their tongues are sharper than Actius his razor; their pens carry farther, and give a louder report than thunder: I had rather stand the shock of a Basilisco, than the Fury of a merciless Pen.—SIR THOMAS BROWNE, *Religio Medici.*

Technical Information—Too Much or Too Little?

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IT has become the custom in recent years to open most discussions of technical information and technical communications on a rather ominous note. As a rule, we are told at the onset that we are faced with an overwhelming problem, that there is too much information being produced, and that we are no longer able to cope with it.

If only to dispel for a brief moment the gray monotony of gloom which seems to overshadow these discussions, I should like to begin by saying that there is, if anything, a shortage of useful technical information in the world today. This thought is based on the observations that the existence of a ton of paper does not necessarily connote the existence of a ton of information and that what may be significant information to one man may be useless verbiage to another.

Related to the foregoing observations is the fact that what may have been useful information last year may be meaningless or useless information this year. People often talk nowadays about making use of the written record of human experience, but they often forget that this record, in science and technology especially, is very ephemeral; it loses its significance and becomes obsolete very rapidly. It has to be used within relatively few years if it is to be used at all.

Sources of Complaint

Just as it has become customary to open up discussions of technical information and communication on a note of sadness, it has been customary to document this sadness with an array of ominous statistics. Most of these statistics will be familiar to readers of this article. There are, for instance, the statistics that in 1950 there were something like 50,000 serial publications in science and technology, and that these publications were at that time producing about 1,850,000 articles and papers a year. Another statistic that has enjoyed great currency in recent years is that we in this country are producing about 150,000 unpublished research reports annually in connection with government-sponsored research. But the most startling statistic of all is that our great libraries are doubling in size every 16 years. I assume that this statistic is startling because I have seen it repeated in any number of papers that I have read in the past couple of years.

Actually, these statistics are very much like the "fillers" that newspapers frequently tuck away in their pages. They are vaguely interesting and perhaps impressive when we read them; they help us to pass the time and to forget momentarily our day-to-day worries; but they do not help us to define or solve very many practical problems.

It is interesting that when we analyze the sources of the complaints about the growth of the literature they seem to come primarily from two groups: the pure or academic scientists, who happen to be the greatest and most effective users of the literature; and the librarians and "documentalists," who are the organizers and disseminators of the literature.

The complaint of the pure scientist seems to center around the fact that too much material is being published in the journals he reads, and that, in order to compress as many papers as possible into each issue of each journal, the average paper is shortened to the point where it becomes practically meaningless. I encountered this complaint very frequently in an interview survey of the scientists of

Johns Hopkins University (*1*). It is a very valid one. Our scientific journals are not giving enough heed to the growth of our scientist population or to the increasing degree of specialization among our scientists. They persist in making one journal do the work of several, and in doing so they very often fail to produce even a single journal that covers adequately the field it is supposed to cover.

In this era of scientific growth and specialization, it is becoming more and more difficult to maintain a single *Journal of the American Chemical Society* or *Physical Review* that can actually do justice to the vast reaches of pure chemistry or pure physics. It is becoming increasingly obvious that if such journals are to serve their intended functions, they will have to be divided into a number of specialized, limited-circulation publications. In this regard, Goudsmit (*2*), writing as editor of the *Physical Review*, has suggested the need for two discrete journals to replace the burgeoning *Physical Review*.

The problem of rising costs resulting from the issuance of several publications in place of one can probably be remedied through smaller print orders and the use of offset or other near-print methods in place of letter press. Pure scientists are less interested in the physical appearance of the publications they read than they are in the ideas they convey. One of the fundamental problems that the pure scientist now faces is that the average paper he reads does not convey enough meaningful information. And so, while many people feel that there is too much information around, the pure scientist is suffering from a real shortage of information.

As might be expected, the cause of complaint among librarians and documentalists is somewhat different from that of working scientists. It has become fashionable in recent years for librarians and documentalists, as the guardians, organizers, and disseminators of the collected written record, to build "straw men" and to point to the tremendous growth of the magnitude and significance of their activities. But if our libraries are in fact doubling every 16 years, a large proportion of the blame must be borne by the library profession.

We librarians and documentalists are rather like the legendary Texas oil millionaire who trades in his Cadillac every time its ash-trays become full. We seem to like to fill up buildings as rapidly as possible and to trade them in for new buildings. The ironic difference between librarians and Texas oil millionaires is that librarians cannot afford Cadillacs, so they go after multimillion dollar buildings instead; and Texas oil millionaires, who are in a position to finance new libraries, are much more interested in new Cadillacs. It would be nice if we could induce some Texas millionaires into the library profession. However, this would probably result in bigger and better library buildings, but it would not alter the sad fact that our research libraries are becoming intellectual graveyards. Librarians must exercise a greater measure of discretion in selecting the materials they add to their libraries and retain in them if they wish to execute their guardianship effectively.

To defend the documentalist against the unfair charge that he is a coconspirator with the librarian in glutting old libraries and building new ones to replace them, it should be pointed out that the documentalist, faced with an overflowing library building, would not attempt to replace it with a new building; his first instinct would be to index or classify its burgeoning collections. The documentalist would probably substitute a multimillion dollar information-retrieval system for the multimillion dollar building of the librarian. This is possibly what differentiates the documentalist from the librarian.

Growth and Use

It is not surprising, when we consider our national statistics, that our supply of technical information has grown; everything else has. During the past 15 years, our national dollar income has more than quadrupled; the number of scientists and engineers in the United States has more than doubled; and the number of scientific and technical students in our colleges and universities has also more than doubled. Our national research budget is more than 6 times as large as it was in 1940.

During this period of expansion, our total population has increased only 25 percent, indicating that a greater and greater proportion of us are becoming engaged in scientific pursuits. If anything, the growth of our scientific literature and information is lagging.

In the course of gathering the foregoing statistics, I happened upon an article in the *New York Times* in which it was shown that the number of telephones per person in the United States has doubled in the past 15 years. Does this mean that the average person has to use twice as many telephones as he did in 1940? Of course not. It simply means that more people are finding more reasons for using telephones than they did 15 years ago. The same is true of technical information.

One of the things that increases the quantity of technical information, and the need for it, is the diversity of purpose for which it is used. A given

piece of technical infomation generally means different things to different persons. The vehicles by which people receive information vary, and the form and intellectual level in which they are able to assimilate it also vary.

An item of technical information, presented in a form that is meaningful to the untrained layman, may seem trivial and redundant to the trained specialist. If it is significant, the trained specialist will probably have read about it already in the technical literature. This same information, written for the trained specialist, may have little or no meaning to the layman, and, if it is to be made meaningful and useful to him, it must be interpreted.

It is this variety in the form and intellectual level in which technical information can be assimilated—this need for interpretation and adaptation—that increases the total amount of technical information which must be produced, if the greatest possible benefit is to be derived from new developments in science and technology.

Need for Market Research

The varying significance and the diverse applications of technical information create a fundamental need for market research to guide its production, storage, and dissemination. Commercial publishers have for many years appreciated the significance of market research. They have depended on market research because they cannot afford to gamble. They have to know that there is an audience for the publications they are producing and distributing; and they have to know the form and content of the information that is most likely to capture and retain this audience. This is a matter of economic survival for the commercial publisher.

Although there are a few exceptions, such as Gray's study of *Physics Abstracts* (*3*), Glass's study of *Biological Abstracts* (*4*), and the recent pilot study done for the National Association of Science Writers to provide information for making science writing and scientific publications more useful (*5*), learned society publishers, contractors who write reports to satisfy the requirements of their contracts, and other information disseminators whose activities are subsidized, do not as a rule make practical use of market research. This can, of course, be attributed to the fact that their livelihoods do not depend directly on audience approval. This is what gives rise to the complaints of scientists that papers are getting so short as to be useless, and this is what gives rise to many other complaints about the way that scientific information is published and disseminated.

It is this failure to recognize and utilize market research that is making libraries and other collections of written and published technical information difficult to use. Instead of complaining about how big our libraries are getting, we should investigate how these libraries are being used, what parts of our growing collections are useful, and what parts are a waste of shelf space.

Like other forms of refuse, stale information is not only wasteful of space, but it can be "toxic." As Philip Morse (*6*) has pointed out in a recent paper on the use of operations research in physics libraries, things in physics that were written 25 years ago are worse than out of date—they are often erroneous. Science grows and matures, as does everything else.

There have been numerous studies of how much time elapses before technical publications fall into disuse, and all of these studies have shown the active life of the average publication in science to be surprisingly short. Fussler (*7*), in a study of the literature references cited by authors in chemistry and physics, has demonstrated that the bulk of such references are less than 10 years old. Hanson (*8*) equated library storage costs and the use that is made of the periodicals in the library of the British Scientific Instrument Research Association. In doing so, he found that the use of periodicals over 13 years old is so slight as to warrant discarding them and borrowing such publications from central depository libraries when the rare need arises. Goudsmit (*2*) has suggested that with the rapid development of physics, it is futile for a physicist to keep more than about six shelf feet of the *Physical Review* as a back collection. Six feet of *Physical Review* now goes back about 5 years. In my own study (*1*), I found that more than 50 percent of the periodicals used by working scientists are less than 5 years old and that, for most purposes in the population studied, a run of periodicals going back 15 years would cover all but a very small fraction of the journals required.

Morse (*6*) has shown in his paper that a five-volume textbook on acoustics, written in 1880, can now be replaced by a single chapter that will omit nothing that was in the five original volumes and that will contain a good deal that was not there. Hutchisson (*9*) has attributed this to the fact that knowledge in the physical sciences is what he terms "accumulative": constant checking, revision, and simplification make previously published works in a field obsolete and reducible to simple, compact presentations in textbook form. And even textbooks become obsolete rather quickly. Buddington (*10*) has shown that the rate of obsolescence of engineering books is about 16 percent a year.

Many librarians and working scientists will voice objections to what they consider the arbitrary limitation of the published materials that are to be stored in libraries. However, if this limitation is based on careful analyses of the actual use that is made of the publications in a library, it can hardly be called arbitrary. If anything, the librarians and scientists who insist on retaining publications in sorely taxed libraries, regardless of whether they are used, are the ones who are being arbitrary.

A basic purpose of market research in dissemination of technical information is to define as accurately as possible the extent and manner of use of a given vehicle of information. These factors will vary from field to field and from publication to publication within a field. However, the temporal value of scientific publications is finite. If the last 20 or 30 years of a given periodical are all that are ever used by the clients of a library, it is an obvious waste to insist on retaining a back run of 40 to 50 years.

Significance of Vehicles of Information

In addition to telling the librarian how long to store the published materials in his custody, market research can furnish him some broad hints about what materials to acquire in the first place. Bradford (*11*) found in studying publications in two fields of science that the bulk of the information on these subjects was contained in a relatively few journals. In one field, 68 journals were found to contain 928 papers on the subject in question; an additional 258 related publications contained only 404 articles. In the other field, 37 journals produced 243 papers, while 127 related journals produced only 152 references. From these figures, it becomes obvious that the cost of trying to have all the available published information on a subject in a single library is likely to be prohibitively great, but that the cost of maintaining most of the available information in a given field is likely to be economically feasible.

It behooves the librarian to ascertain the subject interests of his clientele and to seek out and have in his collection the most productive sources of information in these subjects. This can be done by studying the literature, but probably the best way to do it is by analyzing the publications actually used by a cross-section of the library's clientele. There are sometimes subtle reasons why one publication which publishes no more papers in a given field than several others may be consulted more frequently than the others. The librarian would be wise to look to the scientist reader to find out which are the most useful sources of information in a given field.

Similarly, documentalists, publishers, editors, and other persons concerned with the broader aspects of the dissemination of technical information, in order to do a meaningful job, should ascertain the most effective vehicles for reaching their audiences. For a publication that is already in existence, the publisher would do well to study his audience from time to time to find out how his publication is being used and why it is used the way it is. Such market research will, in most cases, form a basis for needed improvements if the results are accurately applied.

In the case of a contemplated publication, the opportunities are even greater. An understanding of the character, needs, and information-gathering habits of the contemplated audience can often spell the difference between the real success or failure of a new publication. The word *real* is used here advisedly. For a commercially produced publication, the test of real success or failure is very simple. If enough people purchase and read the commercially published publication, and if enough advertisers consider this audience a potential market, the publication is a success. If, on the other hand, revenues from subscriptions, newsstand sales, and advertising add up to an amount that is less than the total cost of producing the publication, it is a failure. It may, of course, be a cultural success, but if there is not a corresponding fiscal success, it will be forced to cease publication or find some form of subsidization.

The subsidized publication need not, and perhaps cannot, apply this simple test. Noncommercial publication projects worthy of subsidization are generally chosen and directed by boards or committees of notables who can hardly be called representative of the market. The subsidized publication, in order to perpetuate its subsidy, has only to please the small group controlling the purse strings. This is a much simpler target to focus on than a widespread audience of readers or seekers of information. However, it is not the group for which the publication is presumably designed. The person who spells the real success or failure of any undertaking in the field of information dissemination is the consumer. He is the person who must be understood and satisfied. Unlike its commercial counterpart, the subsidized publication can enjoy financial success and actually be a miserable failure.

Mention has already been made of three projects, by Gray (*3*), and Glass (*4*), and by the National Association of Science Writers (*5*), which illustrate the use of market research in the improvement of scientific publications. I should like also to make brief mention of another market research project

that a number of nations, including the United States, are participating in at the present time. This project is being sponsored by the European Productivity Agency, which is an outgrowth of the Marshall Plan in Europe. The purpose of the project, which is being carried on through interview surveys in eight countries, is to foster the use of technical information by small- and medium-sized firms in Europe, and, in so doing, to increase the productivity of these firms. The United States, with its proved capacity for production, is serving as a control in the study.

The plan of the survey is quite practical. Instead of spending its limited funds trying out a bunch of devices that might or might not get information to the man who can use it, the European Productivity Agency is trying to find out how this man is now getting whatever information he uses. This will provide a tested route by which he can be reached. And when he is reached, he will not be snowed under with a bunch of technical jargon that he cannot understand and apply. He will get his facts in his own language, and on his own level of learning.

The European Productivity Agency survey is based on two simple premises. The first is that in order to be useful, information, regardless of its form, must be easily understood and easily applied by the consumer for whom it is intended. The second premise, which follows naturally on the first, is that it is much easier, and much better, to design the product to satisfy the consumer than it is to try to alter the consumer to meet the requirements of the product. You can index a book or a paper, or a collection of books or papers, from now until doomsday, but if it does not contain information that is interesting and readily understood by the people who can use it, it will not be used.

Conclusion

I should like to make a plea for a bit of enterprise, preferably free enterprise, in the communication of technical information. It would be good if all of us who are involved in the business of writing and editing and storing and disseminating information would try to evaluate realistically the needs and problems of the people we are supposed to be serving. No matter what we do to improve man and his lot, the average man lives a life of preoccupation with his day-to-day problems. He will not put himself out, if he can help it, to learn about new developments. The new developments have to be presented to him through his normal media of communication. We have to find out what these media are if we are to do him the greatest good.

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Although Experiment is an instrument of immense importance, it is one which derives all its value from the mind directing it. Used at haphazard, its results are fortuitous. The example of the alchemists should teach us how little it effects in incompetent hands; that example discloses experimental investigations wandering into paths more eccentric, and arriving at conclusions more preposterous than ever seduced an ARISTOTLE or an ARCHIMEDES. Experiment is an art, and demands an artist—George Henry Lewes, *Aristotle: a Chapter from the History of Science* (Smith, Elder and Co., London, 1864).

Geomagnetic Program of the International Geophysical Year

E. O. HULBURT

Dr. Hulburt is senior scientist of the U.S. National Committee for the International Geophysical Year. He received his training at Johns Hopkins University and taught there before and after his service in the Signal Corps in World War I. From 1921 to 1924 he taught physics at the State University of Iowa. In 1924 he went to the Naval Research Laboratory, first as superintendent of the optics division and later as director of research. He retired from NRL in 1955. This article is based on a paper presented at the Symposium on the International Geophysical Year that was held during the AAAS Atlanta meeting, 26–31 December 1955.

THE magnetic field of the earth has been used in surveying and navigation for several centuries and in prospecting for minerals and oil deposits for many years. This explains why the terrestrial magnetic field has been under continuous routine observation for more than 100 years by magnetic observatories distributed over the earth. At the present time there are about 80 such observatories maintained by the respective governments of the countries in which they are situated (Fig. 1). Furthermore, geomagnetism has important relations with phenomena of the upper atmosphere such as the ionosphere, radio-wave propagation, and the aurora.

A complete magnetic observatory is a fairly elaborate installation. Its instruments consist essentially of three recording magnets which keep a continuous record of the three components of the earth's field. The instruments are housed in a special building to protect them from weather and changes in temperature, and they are standardized occasionally. The observatory must be remote from artificial magnetic disturbances, such as those due to power lines and heavy electric machines. Several full-time trained people are required to place the recording paper or tape daily, to service the instruments, and to organize the records. Often there are duplicate equipments to reduce the risk of loss of record. In most stations there are two equipments, of high and low sensitivity, respectively, in order to insure that the record will be continuous throughout all phases of magnetic quiet and storminess. In some stations, research equipments have been installed for recording magnetic pulsations of frequencies up to 100 per second and for other special purposes. For mobile field work and at places where only the variations of the magnetic field and not the absolute values are determined, less elaborate equipment is used.

On the basis of the records of the magnetic observatories, it is known that the magnetic field of the earth is fairly stable and unchanging. It is observed, however, that the field undergoes variations, some slow, measured in years, and some rapid, measured in days, hours, minutes, and seconds. The variations, although they involve large amounts of energy (this becomes apparent when it is realized that they envelop the entire earth) rarely amount to more than 2 percent of the permanent magnetic field. They are seldom large enough to disturb a mariner's compass but are easily recorded by the sensitive instruments of the magnetic observatory. Mathematical analysis has shown that the permanent field and the very slow variations are due to magnetic effects of some sort in the interior or in the crust of the earth and that the more rapid fluctuations arise from influences external to the surface of the earth. It is known that these influences are not in the lower atmosphere, and therefore it was concluded that they must be in the upper atmosphere or above.

The main emphasis of the geomagnetic program of the International Geophysical Year (IGY) consists in a series of experiments designed to yield facts about the rapid fluctuations of the magnetic field. These will be recorded by the existing magnetic stations and by new stations to be set up in the polar and equatorial regions. The new stations will of course obtain values of the permanent field as well as of the fluctuations. The fluctuations are known to appear sometimes only in polar latitudes with no effect at the equator, and sometimes to spread simultaneously over the entire earth; fluctuations at the equator only with no effect at the poles are never observed. The fluctuations are usually accompanied by disturbances in radio-wave propagation, by disturbances and changes in the ionosphere, and often by auroral displays. They

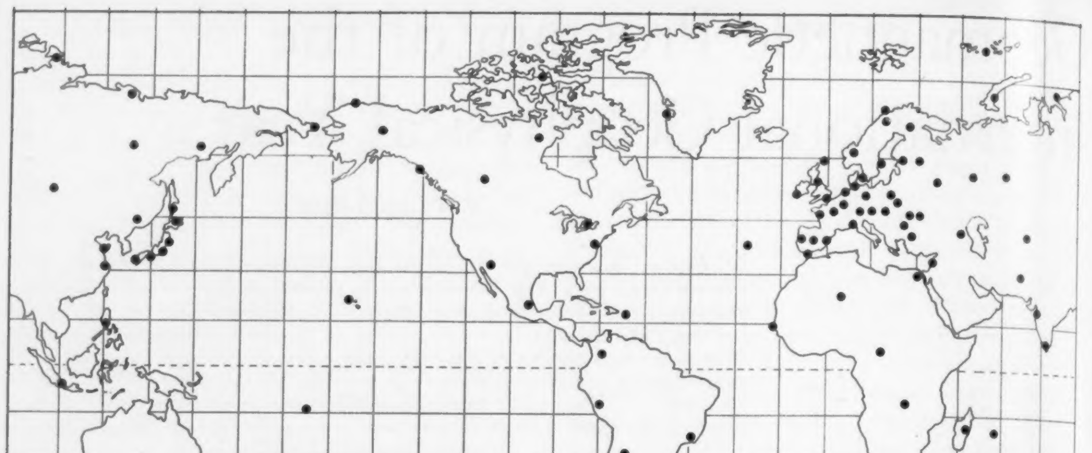

Fig. 1. (Top) Worldwide distribution of magnetic stations.

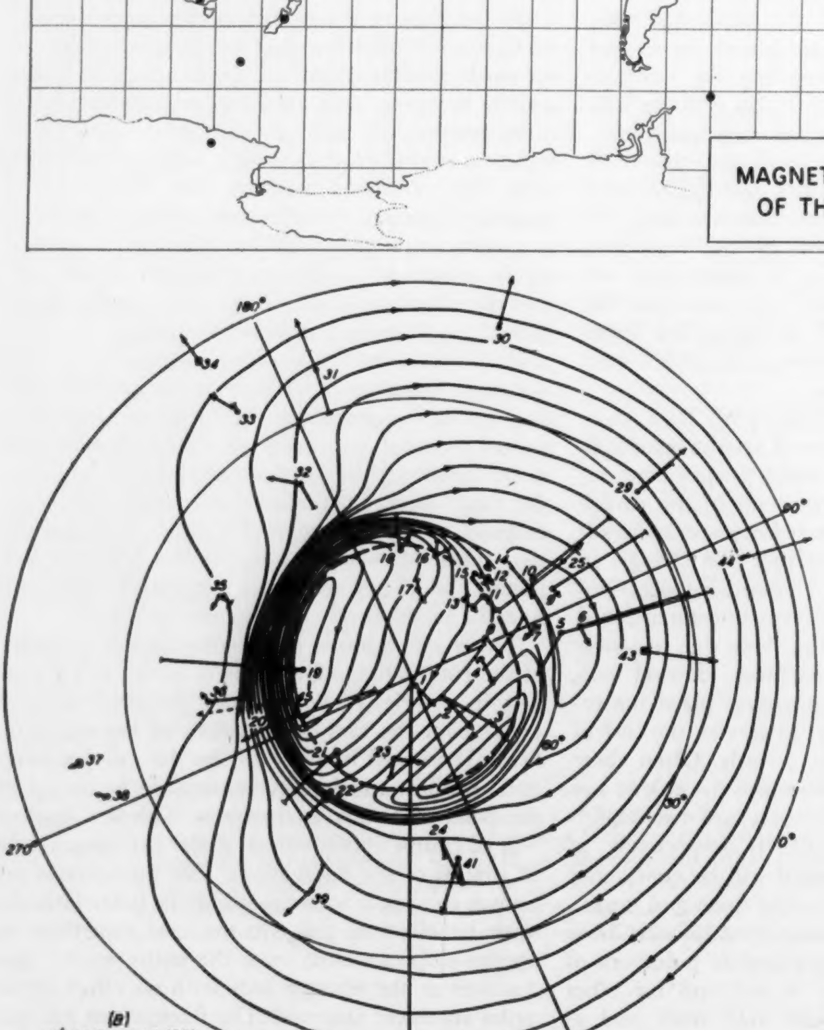

Fig. 2. (Left) Arctic region electric currents inferred from magnetic storm of 1 May 1933. [After Vestine]

increase in number and intensity with an increase in the number of sunspots, and they decrease in number and intensity when the sunspots become less numerous.

The fact that the magnetic disturbances increase and decrease with sunspot number is considered to be adequate proof, and indeed at present the only proof, that they are the result of bursts of radiation of some sort from the sun. The type of radiation is not known, but charged particles, ultraviolet light, and x-rays have been suggested. The manner in which the bursts of radiation cause the magnetic fluctuation likewise is not known, and although various suggestions have been made, none has been developed into a complete theory.

However, it seems reasonable to suppose that the energy from the solar radiation causes winds and increased ionization in the upper atmosphere, and that these in turn cause electric currents which give rise to the magnetic fluctuations observed by the ground magnetic stations. Curiously enough, world-wide analysis shows that the main features of the magnetic disturbances are such as would be caused by three great electric currents, measured in hundreds of thousands of amperes, in the upper atmosphere. One of the currents is in the zone of maximum auroral frequency around the north magnetic pole and across the polar cap, as shown in Fig. 2 for the magnetic storm of 1 May 1933. Similarly, another current is in the southern auroral zone across the southern polar cap, and the third current is around the earth in a broad zone over the equator. The equatorial current, as inferred from the ground-station magnetic data, appears to have an extraordinary belt of greatly increased intensity concentrated in a narrow width of only about 200 kilometers. The demonstration of the existence of these currents, their nature, and their cause is an outstanding problem of geomagnetism.

Only a limited amount of information may be learned about an overhead current from a single magnetic observatory. Much more may be learned from a network of observatories. For example, if the current is in a thin horizontal sheet, its distribution in a horizontal direction and the height of the sheet above the surface may be determined by a suitable network. The spacing of the stations in the net should be roughly of the same magnitude as the height of the sheet in order that the currents may be studied in some detail. If the overhead currents are in the ionosphere, their height above the surface is probably between 100 and 200 kilometers. The usual spacing of magnetic observatories, which is rarely less than 1000 kilometers, is too great. Therefore special networks of magnetic stations are planned for the IGY. By referring to Fig. 1, it can be seen that in Europe and in Japan the density of magnetic observatories is fairly great. However, Europe and Japan are in temperate latitudes and are therefore not in the most critical regions for an investigation of the magnetic storm currents.

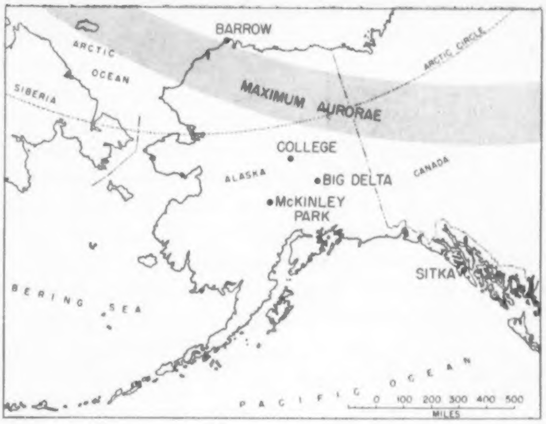

Fig. 3. Magnetic stations in Alaska.

It may be recalled that the United States, through the Division of Geophysics of the Coast and Geodetic Survey, operates at present seven complete magnetic observatories at San Juan, Puerto Rico; Fredericksburg, Virginia; Tucson, Arizona; Sitka, College, and Point Barrow, Alaska; and Honolulu, Hawaii. These of course will continue to operate during the IGY. In addition, the

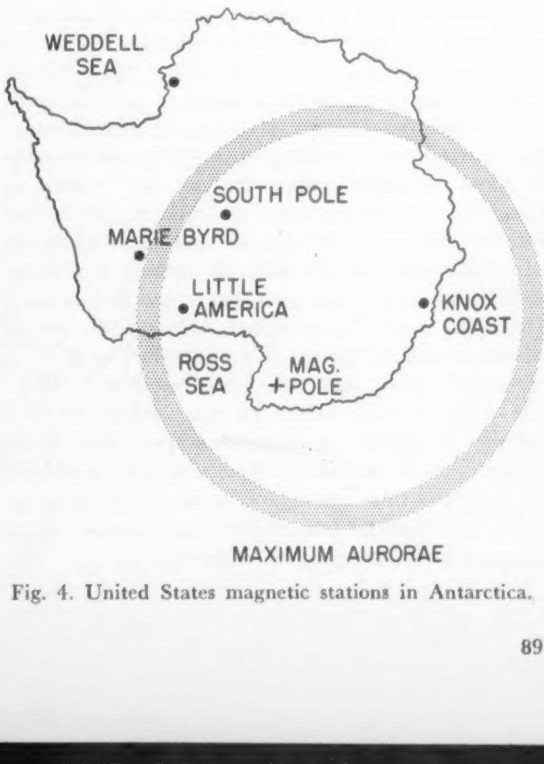

Fig. 4. United States magnetic stations in Antarctica.

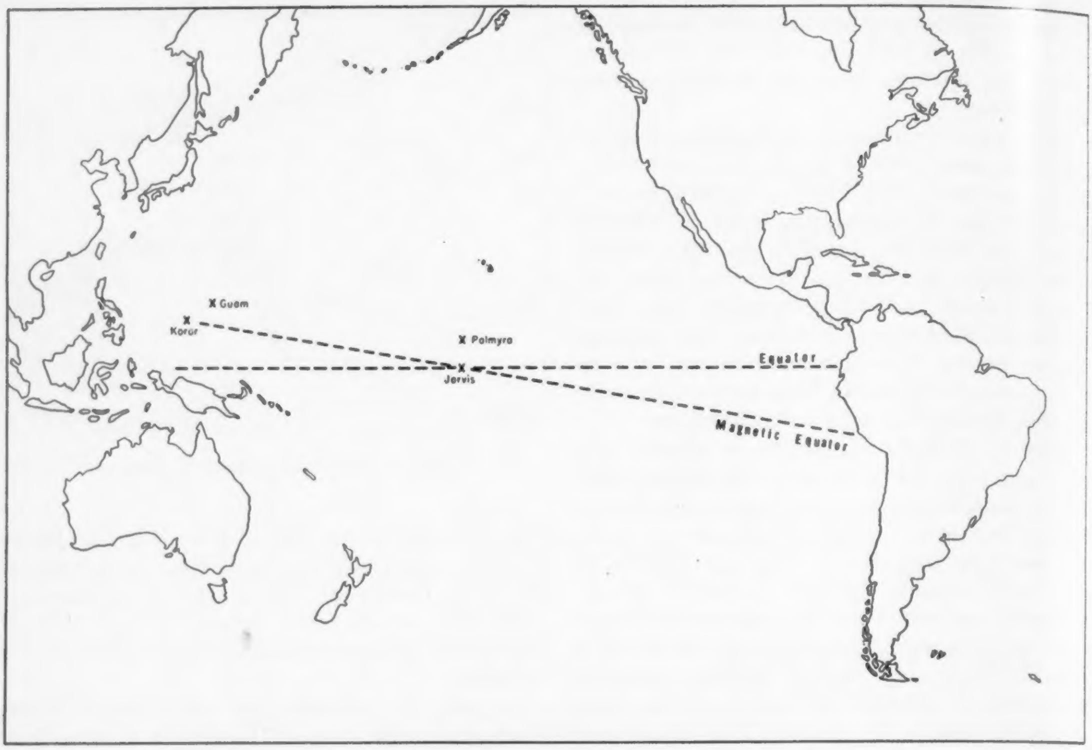

Fig. 5. United States magnetic stations in the Pacific Ocean.

Geomagnetism Panel of the U.S. IGY committee has worked out the following program. This panel has the following members: L. R. Alldredge, W. Elsasser, E. O. Hulburt, R. R. Revelle, E. B. Roberts, M. A. Tuve, V. Vacquier, and E. H. Vestine.

Alaska. There will be five stations in Alaska, at Sitka, College, Point Barrow, McKinley Park, and Big Delta; the last two are new stations. As shown in Fig. 3, these stations spread across the northern zone of maximum auroral frequency and the zone of the electric currents of magnetic disturbance; they provide an excellent network to obtain data in these important zones. In fact, it is about as effective a broad northern network as can be arranged within the rather restricted limits of accessible land areas. In addition, the station at College will be equipped with two sets of satellite stations (with automatic variographs). One set will consist of four stations about 250 kilometers distant in directions north, east, south and west of College; the other set will consist of two stations about 8 kilometers distant in directions west and south. These sets of satellite stations will give improved data on the time and space gradients of the magnetic disturbances from which the features of the overhead currents may be deduced.

United States. In addition to the present observatories, there will be a network of stations consisting of an east-west chain of five stations stretching about 1200 kilometers across some of the western states, with a shorter north-south, cross-arm chain of three stations. The stations will be about 300 kilometers apart and will provide a closer network for temperate latitudes than has been available heretofore. The exact location of all these stations has not yet been decided. Climax, Colorado will be a common point of the two chains.

Rapid magnetic fluctuations. Five of the foregoing stations (the exact ones not yet chosen) will be equipped with tape recorders to record magnetic-field fluctuations in the frequency band from 1 to 50 cycles per second. These stations will collect data bearing on the question whether the fluctuations in this band are due to electromagnetic radiation fields as from lightning discharges at a distance or from induction fields as from ionospheric currents overhead.

Antarctica. Stations will be established in Antartica at Little America, Marie Byrd Land, and at the south geographic pole. If possible, a fourth station will be installed in the Weddell Sea region. As indicated in Fig. 4, these stations will constitute

a net spreading across the southern zone of maximum auroral frequency and the zone of the electric currents of magnetic disturbance.

Pacific islands. There will be four stations in the Central Pacific Ocean at Guam, Korror, Palmyra, and Jarvis islands. These will cover the region of the equatorial electric current. In Fig. 5, it is seen that the stations are in pairs, one station of each pair, Korror and Jarvis, being on the magnetic equator. In addition, Jarvis has the somewhat mystical importance of being very close to the intersection of the earth's magnetic and geographic equators.

In conclusion, it is believed that this program, carried on throughout the period of the International Geophysical Year, will provide valuable new information on the fluctuations of the earth's magnetic field and that it may answer many questions about the fundamental causes of the fluctuations. It is realized, however, that complete information probably cannot be derived from magnetic observations alone at the surface of the earth. The surface magnetic data must be supplemented by data from rockets in the upper atmosphere, by radio-wave propagation data, by information from ionosphere stations, and by auroral and solar observations. The foregoing geomagnetic program has been designed with great care to supplement and to be supplemented by the programs of these other disciplines.

To suggest that a [university] graduate is, or ought to be, a higher type of citizen than the man whose gifts do not lead to a university education is to misunderstand the nature of citizenship in a democratic community. It has a totalitarian ring about it, and is calculated to arouse indignation in many manual workers who feel, and rightly so, that their conviction of what constitutes the basis of a sound social order is entitled to as much respect as that of the intellectual. . . . Society will choose its own leaders; wisely, we hope, but certainly for qualities in no way connected with academic distinction. . . . But society will also need, for its great task of restoration, men and women of high ability and intensive training in each of the sciences—and the humanities, too—and will welcome them, not as superior world citizens, but for the special contributions which their scientific education enables them to make. The education and training of these experts is the special function of the university, from which it should not be deflected. For the undergraduate who has the abilitiy . . . the eager pursuit of the training which is to fit him for this task is his best form of social service.—J. A. Crowther, *Nature* **151**, 171 (1943).

Hermann von Helmholtz: Nineteenth-Century Polymorph

HOWARD GRUBER and VALMAI GRUBER

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FEW scholars in any branch of knowledge have left so varied a record of research and discovery as Hermann Ludwig Ferdinand von Helmholtz, German physician, physiologist, psychologist, physicist, and mathematician. A man of tremendous energy and curiosity, he produced more than 200 articles and books, among them a classic paper on the conservation of energy, a great handbook of physiological optics, and a treatise on the physiology and psychology of sound. In the course of his experimental work, he invented many instruments, including the ophthalmoscope, ophthalmometer, and telestereoscope. Shortly after his teacher, Johannes Müller, declared that it was impossible to measure the velocity of the nerve impulse, Helmholtz measured it. An avowed empiricist, he took issue with the philosophy then prevailing in Germany, the intuitionism of Kant. His career provides a rewarding study of the effects of a broad, disciplined education, the lifelong influence of a few guiding ideas, and the mutual stimulation of scientific research and university teaching (*1–3*).

When he died in 1894, the *Physical Review* (*4*) gave him a six-page obituary, and the *Nation* (*5*) wrote, "Dr. Hermann Helmholtz . . . the acknowledged and worshipped head of the scientific guild, is gone." Considering his career of fundamental accomplishment, the obeisance at his death is not surprising; the interesting point about the man is that even when he was very young his work had the mark of a master.

Life

A remarkably consistent pattern can be seen in much of Helmholtz' work. He began with simple observation of concrete phenomena, and, because he was a keen observer and an inventive experimenter, new facts quickly came to light. These in turn led, often very soon, to theoretical work on a highly abstract level or to experimental study of the more general aspects of the problem with which he began. Frequently, his starting point was simply a demonstration of supposedly well-known facts that he had prepared for his students because he did not care to lecture about phenomena he had not seen for himself.

The boundaries between disciplines never troubled him: starting with physiology, measuring the heat generated by muscular contraction, he was led to the physical problem of the conservation of energy, and he solved it with consummate skill. Starting with color vision (is it psychology, physics, or physiology?) he was led eventually to non-Euclidean mathematics and the consideration of n-dimensional manifolds. He moved with agility over the whole domain of science; and from the very first he saw the scientist's task as the reduction of the whole of nature to an integrated body of fact and law.

Born in Potsdam in 1821, Helmholtz spent his first 7 years at home, where he was taught by his father, a teacher of German in the *Gymnasium* and a man devoted to science and philosophy. His mother was Caroline Penne, a descendant of the Quaker, William Penn. Helmholtz spent his entire scientific career in the German university system. He married twice; his first wife, whom he married in 1849, died 10 years later, leaving one son and one daughter. He married again in 1861 and had another son and daughter. Of his four children, his elder son became a civil engineer, his second son died at the age of 33, and his two daughters married, respectively, a geologist and the head of an electric instrument firm. His second wife was apparently a lady of "high social station" who organized brilliant musical evenings and attracted to their home a number of the distinguished artistic and scientific figures of the day. Hereditary nobility was conferred on Helmholtz by the German emperor in 1883.

In 1893, he paid his only visit to the United States and attended the World's Fair at Chicago.

On the way home, he suffered a fall on board ship from which he never completely recovered; he died in 1894 at the age of 73.

In an autobiographical sketch (*6*) Helmholtz said that he had a "bad memory for disconnected things"; possibly one indication of this failing was his inability to distinguish left from right. But he loved great poetry, and when he was in high school he could recite "some books of the Odyssey, a considerable number of the odes of Horace, and large stores of German poetry."

Later, he became more and more interested in nature, in geometry, and in the laws of physics—but all in the light of a specific fascination with the idea, in his own words, of "the intellectual mastery over Nature . . . by the logical force of law." At school, when his class was reading Cicero or Vergil, both of whom he considered "very tedious," he was calculating, under his desk, the paths of rays of a telescope; and he spent some time constructing optical instruments out of spectacle glasses and his father's botanical lens.

Although Helmholtz wanted to study physics, when he was ready to enter a university his father pointed out that the study of physics was a poor way to make a living and suggested that he could reach his goal through the study of medicine. So he entered the army medical school in Berlin, the Friedrich Wilhelms Institute, which offered financial help to those students who needed it—among them Helmholtz.

In Berlin he met and came under the influence of one of the founders of modern physiology, Johannes Müller, who was then teaching at the University of Berlin. Helmholz attached himself to the academic circle around Müller and also met Gustav Magnus, professor of physics, whom he was one day to succeed. Here too he found his greatest friends, both of them students of Müller: Du Bois-Reymond, later professor of physiology at Vienna, and Virchow, who became professor of pathology at Berlin.

As students, Helmholtz and two of his companions, Brücke and Du Bois-Reymond, rejected the vitalistic theories that were then still prevailing. All under 30, all beginning great careers in physiology, they joined in a pact to combat vitalism. Indeed, Brücke and Du Bois-Reymond took a solemn oath to prove and expound the principle that "no other forces than common physical chemical ones are active within the organism."

Two of Helmholtz's earliest researches were modest efforts toward that end. In one he dealt with the processes of putrefaction and fermentation. In the other he dealt with the development of heat in muscular action, using a thermocouple

Fig. 1. Helmholtz in 1848 at the age of 27, the year after he wrote his classic paper on the conservation of energy. [From Koenigsberger, *Hermann von Helmholtz*, p. 54.]

to measure the heat given off in muscular contraction. This physiological work led him to some very general considerations about the nature of energy, and in 1847 he read his classic paper, "Uber die Erhaltung der Kraft," before the Physical Society of Berlin.

Conservation of Energy

Helmholtz had been thinking about the conservation of energy for years, his interest stemming first of all from biological issues. As a boy, he had heard his father's circle of friends discuss the theory of vitalism. What was the source of the energy displayed by living forms? they asked. Helmholtz wished to criticize the then prevalent notion that living organisms are governed by an "indwelling vital force"—that is, not governed by the physicochemical laws of nature. His purpose, so he said, was simply to organize the facts and present a "critical investigation for the benefit of physiologists."

This modest aim was more than gratified. Starting from empirical work in physiology, he quickly moved to mathematical physics. The idea of energy conservation was almost overripe by that time, having been approached from technological, metaphysical, and experimental points of view. Many

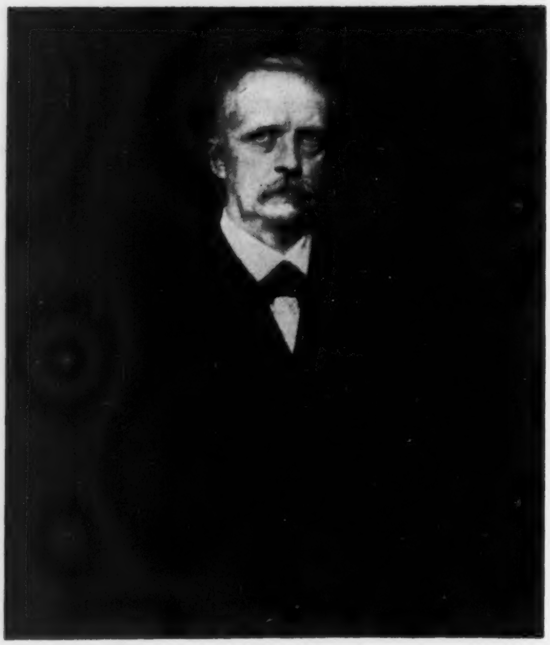

Fig. 2. Helmholtz in 1876, "An irresistible driving power" (Maxwell). [From Koenigsberger, *Hermann von Helmholtz,* frontispiece.]

had preceded Helmholtz in expressing this idea with varying degrees of clarity. In France there had been Carnot and Séguin; in Denmark, Colding; in Germany, Mayer; and in Great Britain, Joule (*7*). But Helmholtz' theoretical analysis played an important part in establishing the principle in its central physical role. It was characteristic of the man that he developed the concept in a highly mathematical form from a few theoretical premises concerning the particulate nature of matter and the forces acting between these particles.

Its theoretical character, indeed, was the reason that was given for a refusal to publish the paper, although, to be sure, the leading physicists of the day were not at all certain of the validity of the principle. On his death in 1894, the *Physical Review* wrote that Helmholtz' paper had "come to be recognized as chief of the early attempts to give expression to the principles upon which, later, the doctrine of energy was to be built . . ." (*4*).

In the history of science, Helmholtz' paper can be given no credit for priority, but the scientists of his day recognized its value nonetheless. Clerk Maxwell said (*8*), "To appreciate the scientific value of Helmholtz' little essay on the Conservation of Force, we should have to ask those to whom we owe the greatest discoveries in thermodynamics and other branches of modern physics, how many times they have read it over, and how often during their researches they felt the weighty statements of Helmholtz acting on their minds like an irresistible driving power."

The paper had its reverberations among biologists as well. In a moving remembrance, Du Bois-Reymond describes the circle of Johannes Müller's disciples, of which both he and Helmholtz were members. Müller was one of Germany's great scientists and a key figure in turning German biology from *Naturphilosophie* to scientific empiricism. Nevertheless, he remained a vitalist, and this point of view stood in the way of further progress. Helmholtz' paper on the conservation of energy, promoting as it did the physicochemical analysis of energy transformations in living matter, was a liberating influence, freeing the circle of young scientists from their *"vitalistischen Träumereien"* (*9*).

There was later a fierce controversy over scientific priorities. In England, there was a very bitter exchange between Lord Kelvin and John Tyndall, the former supporting Joule's claims and the latter Mayer's. In Germany, Eugen Dühring espoused Mayer's claims, hailing him as the "Galileo of the 19th century." Dühring, who wrote a very bitter and personal attack against Helmholtz, eventually lost his post as lecturer in philosophy at the University of Berlin, and went on to write a great deal in a paranoid and racist vein. Helmholtz seems to have stood aside during this dispute, freely acknowledging the others' priority when he learned of it. He and Tyndall were good friends long after, and Tyndall translated much of Helmholtz' work.

It is little wonder that the scientists of the day worried over the issue of priority. They recognized, as do modern historians of science, that the principle of the conservation of energy was probably the most far-reaching scientific advance of their age. In our own age of ever-increasing specialization, it is noteworthy that both Helmholtz and Mayer were led to their formulations of a fundamental physical principle by the consideration of biological problems.

In any case, at the time he read his paper, Helmholtz was a 26-year-old army surgeon in the obscure garrison town of Potsdam. His work resulted in an invitation from the University of Königsberg; the army released him from further duty, and he took the chair of physiology there in 1849. It was during his 6-year stay at Königsberg that he devised a way of measuring the speed of the nerve impulse, invented the ophthalmoscope and the ophthalmometer, and began his work on physiological optics.

Contribution to Physiology

The scientific opinion of the time, including that of Johannes Müller and Du Bois-Reymond, held that the velocity of the nerve impulse was too rapid to be measured—probably being comparable to the speed of light. One estimate given was 60 times the speed of light! In 1842, in his first published paper, his medical thesis, "De fabrica systematis nervosi evertebratorum," Helmholtz showed that nerve cells of ganglia are individually connected to the nerve fibers that lead from them. This demonstration helped to fill out the emerging picture of the nervous system as a complex network for the transmission of signals. And in 1850 we see Helmholtz resuming work in this area, this time to measure the velocity of the nerve impulse. Using a pendulum myograph of his own invention, he found that the speed of the nerve impulse of a frog was less than 90 feet per second, or less than one-eighth of the speed of sound. He also conducted experiments to discover the speed of the nerve impulse in human sensory nerves by stimulating his subjects on the toe and the thigh and noting the difference in reaction time.

The state of knowledge at the time of this discovery is reflected in a letter Helmholtz' father wrote him soon afterward: "As regards your work, the results at first appeared to me surprising, since I regard the idea and its bodily expression, not as successive, but as simultaneous, a single living act, that only becomes bodily and mental on reflection: and I should as little reconcile myself to your view, as I would admit a star that had disappeared in Abraham's time should still be visible."

About his invention of the ophthalmoscope in 1851, Helmholtz was deprecatory; it began merely as a demonstration to his students that when eyes glisten in the dark, it is due to reflected light, not to their own luminosity. In the course of this work, Helmholtz wanted to produce a thorough analysis of the relationship between incident and reflected rays. This led to the invention of the ophthalmoscope. Helmholtz maintained that Brücke had been "within a hairsbreadth" of it. (Charles Babbage, in England, had already devised a crude ophthalmoscope, of which Helmholtz was unaware.)

Helmholtz describes the way in which he worked, once he had formulated the problem: "The instrument was at first difficult to use, and without an assured conviction that it must work, I might, perhaps, not have persevered. But in about a week I had the great joy of being the first who saw clearly before him a living human retina."

As the news of his invention spread, so also did his fame. Helmholtz began to visit England, where he found, in a sense, an intellectual home. His philosophy and his psychological empiricism were more in tune with the ideas of Locke and John Stuart Mill than with those of Leibnitz and Kant.

At home, he found the gulf between himself and his older colleagues too wide for comfort. He describes the feeling, still prevalent among physicians of the time, that auscultation and percussion of the chest, though practiced in hospital wards, were "a coarse mechanical means of investigating which a physician with a clear mental vision did not need; and it indeed lowered and debased the patient, who was anyhow a human being, by treating him as a machine" (*6*).

Helmholtz himself was told by a surgeon colleague that the ophthalmoscope should not be used because it was dangerous to admit crude light into diseased eyes; another colleague insisted that the instrument was obviously meant for use by those with poor sight—because his own sight was good, he did not need it.

Perhaps Helmholtz exaggerated the coolness with which his invention was received. It is said that when the leading ophthalmologist, Von Graefe, first saw the living human retina, he exclaimed, "Helmholtz has unfolded to us a new world! What remains to be discovered?" Certainly, Von Graefe wrote in this vein in the inaugural issue of the *Archiv für Ophthalmologie* in 1854.

Helmholtz' answer to unscientific colleagues was to be ever more scientific. He tells the story of a professor of physiology who indignantly refused the invitation of a physicist to watch an experi-

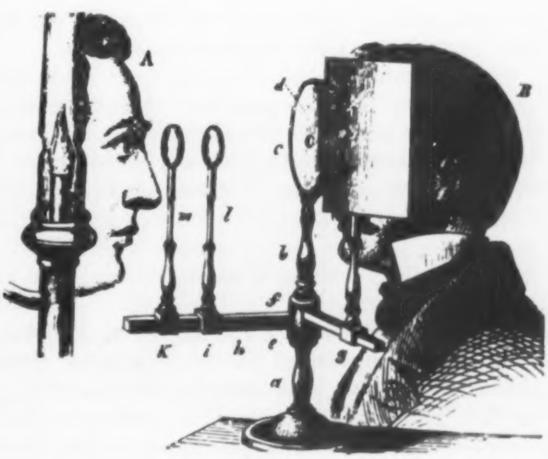

Fig. 3. An early form of ophthalmoscope. [From *Physiologische Optik*, published in 1896, p. 225.]

ment; experiments, he said, are not for physiologists. Another distinguished acquaintance, a professor of therapeutics, tried to persuade Helmholtz to devote himself to the "really intellectual part" of physiology and to leave the experiments to the lower class of scientists. "He quite gave me up," says Helmholtz, "when I said that I myself considered experiments to be the true basis of science."

His impressions of the scientific climate of 19th-century England are interesting. In his lecture on academic freedom, he compared the educational systems of several European countries, and expressed particular surprise at the different distribution of scientific talent in Germany and in Great Britain. Most of the eminent scientists of Germany were attached to one or other of the universities; this situation gave rise to the "not infrequent jest or sneer," as Helmholtz says, "that all wisdom in Germany is professorial wisdom." In England, on the other hand, Helmholtz saw men such as Humphry Davy, Faraday, Mill, and Grote who had no connection with any university; Davy and Faraday were retained by the Royal Institution, a private society that organized public lectures on the progress of natural science.

Helmholtz felt, however, that the German universities of the day afforded an atmosphere of intellectual freedom that was not to be found in other countries. Intellectual leaders in the rest of Europe, he thought, were able "and as it would seem with perfect conscientiousness, to restrain the inquiring mind from the investigation of those principles which appear to them to be beyond the range of discussion, as forming the foundation of their political, social and religious organization; they think themselves quite justified in not allowing their youth to look beyond the boundary which they themselves are not disposed to overstep."

He took pride in the fact that there could be taught in any German university "the extremest consequences of materialistic metaphysics, the most daring speculations on the basis of Darwin's evolutionary theory, and the extremest deification of papal infallibility."

Color Vision

It was while he was at Königsberg that Helmholtz became interested in the theory of color vision that had been profounded by Thomas Young in 1807. The eventual result of this interest was his enormous *Handbuch der Physiologischen Optik,* the first volume of which was published in 1856. The complete work, which did not appear until 1867, did contain the Young-Helmholtz theory of color vision, but it had also become an encyclopedic treatment of the entire subject of vision from a physical, physiological, and psychological point of view.

His own account of the manner in which this work began is characteristic: "Not being inclined to describe in my lectures things I had not myself seen, I made experiments in which I blended the colors of the spectrum in pairs. To my astonishment, I found that yellow and blue gave not green, as was then supposed, but white. Yellow and blue pigments, when mixed, no doubt gave green, and until then the mixing of pigments was supposed to produce the same effect as the mixing of the colors of the spectrum. This observation not only at once produced an important change in all the ordinarily accepted notions of color mixture, but it also had an even more important effect on my views. Two master minds of the first rank, Goethe and David Brewster, were of the opinion that yellow and blue could be directly seen in green. Their observations were made with pigments, and they thought they could divide their perception of the resulting color into two parts, yellow and blue, while in reality, as I was able to show, neither was present. I was thus drawn over to the empirical theory of perception, and it indicates even now the contrast between my position in the theory of color perception and that of Hering and his followers, who hold firmly to the opinion that one can decompose the perception into its component parts" (*3*).

From this beginning, Helmholtz soon developed the theoretical distinction between additive and subtractive color mixing and a device for superimposing one spectrum on another so that every combination of spectral colors could be directly observed. His observations led him to a modern three-factor theory in which every experience of color can be described in terms of hue, saturation, and intensity.

In 1855 Helmholtz went to Bonn, again as professor of physiology. Two years later, he accepted the same chair at Heidelberg. He was then 37 years old, and he was to remain there for 13 years.

While he was at Heidelberg, Helmholtz finished the second volume of the *Optik* and published the whole work. Meanwhile, he was also working on his book, *The Sensations of Tone* (*Tonempfindungen*), which he published in 1863.

The *Physiological Optics* is a magnificent work —it expounds virtually all the information that was then known concerning vision, carefully analyzing theoretical controversies and adding much to the store of knowledge and theory.

The work (*10*) is divided into three main parts. The first, "The dioptrics of the eye," deals with the eye as an optical system. An important chapter in this section correctly explains the mechanism of

accommodation. Among many earlier theories, Thomas Young had thought that the lens was itself muscular tissue, changing shape in order to provide sharp focusing. But Helmholtz showed that there were no nerve fibers leading to the lens and that direct electric stimulation of an extirpated lens did not produce any reaction, whereas electric stimulation of the ciliary muscle did produce changes in the curvature of the lens. Thus Helmholtz provided the modern theory of the mechanism of accommodation: the crystalline lens of itself tends toward a spherical shape, but the force produced by the surrounding ciliary process pulls it into a flattened shape. The curvature of the lens at any moment is due to the balance between these two sets of forces, and since the one is a constant, the curvature of the lens is directly controlled by the ciliary muscle.

The second main division of the *Optik*, "The sensations of vision," deals chiefly with the light-sensitive organ, the retina itself. The theory of color vision is presented in essentially the same form as it had been first expounded by Thomas Young. Some of the other topics treated include various phenomena of the blind spot, the insensitivity to light of the optic nerve, the subject of visual acuity, color mixture, after-images, and contrast. Every medical student has seen Helmholtz' figure for roughly demonstrating the position of the blind spot where the optic nerve enters the eye.

The third part, "The perceptions of vision," is mainly psychological. Here Helmholtz advanced his empirical theory of space perception. His fundamental principal was that "the sensations of the senses are tokens for our consciousness, it being left to our intelligence to learn how to comprehend their meaning." He argued assiduously against the theory that the perception of spatial relations is innate. Helmholtz believed that the information provided by sense data at any moment is frequently insufficient; the perceiver resolves such puzzles by a process of "unconscious inference," supplementing his present supply of sense data with previously acquired information. This doctrine of "unbewusster Schluss" is currently in great vogue among psychologists. Whatever the merits of the empirical theory of space perception, it is unfortunate that modern psychologists have tended to utilize Helmholtz' theory only in explaining that we learn to recognize specific objects, while often ignoring the more fundamental aspect of Helmholtz' views—that we also learn the general properties of the space we inhabit. The latter idea proved to be of greater interest to Helmholtz as he pursued his mathematical analysis of the nature of space.

Both in his *Physiological Optics* and in his *Sensations of Tone*, one of the leading ideas was the doctrine of specific nerve energies, which he took and extended from the work of his teacher, Johannes Müller. As Helmholtz expounded the principle, there is a small number of types of sensory receptors, each type particularly sensitive to energy of certain wavelengths. The sensations consist of the excitation of various combinations of these receptors. The Young-Helmholtz theory of color vision is a form of this principle, involving three types of receptor. In his auditory theory, Helmholtz postulated that the organ of Corti comprised perhaps 4200 tuned resonators that produce the entire gamut of auditory experiences by vibrating in any of a very large number of combinations.

In his *Tonempfindungen*, Helmholtz drew on his vast erudition in music for support of his empirical theory on musical esthetics—that the laws of harmony and progression are artistic inventions, not the inexorable results of the properties of the human ear (*11, 12*).

A minor accomplishment of his at this time was the detection of the microorganism that was responsible for his hay fever. He examined his nasal discharges under a microscope both in what was for him the hay fever season—mid-May to the end of June—and out of season, and decided to try quinine drops as a weapon against the microorganism he found. He prepared a "neutral solution of sulfate of quinine (1:800)," administered 4 milliliters to each nostril, and, as reported in *Nature* in 1874, the remedy worked (*12*). A subsequent issue of *Nature* mentions several reports from others who had read of Helmholtz' remedy and who had also been successful in banishing their symptoms.

Physics and Mathematics

In 1871, Helmholtz was at last to return to his first love, physics. Gustav Magnus, professor of physics at Berlin, had died in 1870, and Helmholtz was offered the job. He took it and remained professor of physics at Berlin until his death in 1894.

In these 23 years, Helmholtz continued work in mathematics and in many branches of physics. He revised the *Optik* and the *Tonempfindungen*, and in 1878 he published *Die Thatsachen in der Wahrnehmung*. In 1887, he was appointed director of the Physikaltechnisches Institut, Charlottenburg.

His famous paper on vortex motion, published in 1858, began a long series of contributions to hydrodynamics. Interesting as this development was in its own right, the emergence of a striking identity between the equations of hydrodynamic

and of electromagnetic phenomena was of equal import. Helmholtz applied hydrodynamic principles to the analysis of meteorological problems as well.

From 1866 on, he had been arguing that geometrical axioms were the products of experience, and not, as Kant and Fichte had maintained, a priori intuitions. Riemann's work had preceded his by some 10 years, but Helmholtz approached the issues from another side, and his work hastened the acceptance of non-Euclidean geometry. Helmholtz was led to the subject through his work in sensory psychophysiology: human experience requires an n-dimensional manifold to encompass dimensions of experience such as visual space, the system of colors, and the system of sounds. The properties of each continuum in this manifold present a separate empirical question. One of his main themes is that the principle of congruence underlies all geometries and that in Euclidean geometry it is taken for granted that a figure can be moved in various ways without changing its size or shape. This is a mechanical principle, not a geometric one, he argues, and can be verified by measurement. He describes various spaces, such as an egg-shaped surface, in which it would not be true. His conclusion is that pure Euclidean geometry cannot be verified as a description of reality unless it is taken together with certain mechanical principles. "The axioms of geometry," he wrote, "taken by themselves out of all connection with mechanical propositions, represent no relations of real things. . . ." This is true of all geometries, but, "As soon as certain principles of mechanics are conjoined with the axioms of geometry, we obtain a system of propositions which has real import, and which can be verified or overturned by empirical observations, just as it can be inferred from experience" (*6, 13*).

Helmholtz' speculations along these lines were enthusiastically taken up by certain scientists—notably by Zöllner, the Leipzig astronomer, who maintained that the American medium, Slade, could be accomplishing his apparent "miracles" by the use of a fourth dimension. A heated controversy broke out, and Helmholtz was accused of causing a "scientific scandal" and encouraging "mathematical mysticism." Even his great admirer, G. S. Hall, felt bound to administer a mild rebuke to the originator of the "scandal": after calling the charges against Helmholtz "extravagant condemnation," he goes on to say, "We cannot however entirely acquit Professor Helmholtz from the charge of making an indiscreet appeal to the scientific imagination," and solemnly remarks that even "lower intelligences" had been misled by the controversy, as evidenced by the "reported statement of a laborer at a Leipzig socialistic gathering that a great scholar in Berlin claimed to have discovered heaven" (*2*).

In 1878, Helmholtz propounded a research problem on electromagnetic effects in unclosed circuits for a prize to be awarded by the University of Berlin. With Helmholtz' encouragement, Heinrich Hertz undertook the research, won the prize, and went on from there to do the experimental work that verified Maxwell's theoretical derivation of the wavelike character of electric phenomena and that constituted, in fact, the discovery of radio waves. Thus, although Helmholtz himself may be regarded as representing a culmination of classical physics, he also played a role of some importance in the origins of modern physics. This is also true, perhaps, of his work on the conservation of energy. Although this work was only an application of Newtonian principles, it may be argued that the clear-cut formulation of the law of energy conservation was necessary before it could be replaced, scarcely 50 years later, by the law of mass-energy conservation. (The law of mass conservation had already been established by the chemical researches of Lavoisier and others in the late 18th century).

Scientist and Teacher

As a man, Helmholtz seems, from his writings and his lectures, to have been modest about his scientific achievements. He always insisted on giving much credit to his forerunners and coworkers, and emphasized the importance of luck in experimental research. In one of his popular lectures, he described how his bright ideas came to him: "They often came actually in the morning on waking, as expressed in Goethe's words. . . . But, as I have stated in Heidelberg, they were usually apt to come when comfortably ascending woody hills in sunny weather. The smallest quantity of alcoholic drink seemed to frighten them away."

As a teacher, he seems to have rather disdained the current trend toward spectacular methods in the teaching of science. According to contemporary writers, the custom of the time was for each scientist to try to outdo all other scientists in this respect: they used huge charts that could be raised and lowered mechanically, a darkened auditorium for showing slides, large models of the eye and the ear, and "hundreds of animals, large and small . . . sacrificed, and in one case even a horse . . . introduced to show heart action." Textbooks were "almost useless . . . except for review"; the trend was all toward demonstration, and several assistants were kept continually occupied by each lec-

turer in preparing for the next day's lecture. One chemistry laboratory—that of Kolbe—was decorated with the motto: "God made the world according to number, weight, and measure."

Helmholtz apparently left these elaborate demonstrations to his assistants and taught a small group of advanced students with no other aid than a blackboard. On this he would work out complicated equations, sometimes finding errors in his calculations, and always preferring to work out problems as he went along rather than to prepare every lecture beforehand. According to Hall, he had a habit of thinking out loud in lecture room and laboratory, and he used to spend some hours each day discussing experiments with his student assistants. But all these attributes, which might seem progressive today, apparently could not eradicate the impression—at least as far as Hall was concerned—that Helmholtz was a man "far more gifted in discovery than in teaching" (*2*). During this period, however, Helmholtz had at least one very great pupil, Heinrich Hertz.

Helmholtz took the whole of experimental physical science for his field, and he himself attributed much of his success to this catholicity of taste and talents: "Possessing some geometrical capacity, and equipped with a knowledge of physics, I had, by good fortune, been thrown among medical men, where I found in physiology a virgin soil of great fertility; while, on the other hand, I was led by the considerations of the vital processes to questions and points of view which are usually foreign to pure mathematicians and physicists."

On the face of it, Helmholtz was not much concerned with the political or philosophic controversies of the 19th century or with its great social changes. But the post-Hegel years, in which he began his career, were years of great ferment. The materialistic outlook that guided his work from youth onward was not an individual decision but the work of a group of young scientists in Berlin. His triumphant career in the universities was not merely a reward for personal virtue but a reflection of the strength of science in those institutions—a strength that grew as the German nation emerged in the 19th century.

In the field of natural science, he was living in exciting times, and he knew it. Again and again in his lectures, he referred to the sadly old-fashioned tenets and methods held and practiced in his youth. "When I go back to my earliest recollections, . . ." he says, "when I began to study physics out of the schoolbooks in my father's possession, . . . I still see before me the dark image of a series of ideas which seems now like the alchemy of the Middle Ages. Of Lavoisier's and of Humphry Davy's revolutionary discoveries, not much had got into the schoolbooks. Although oxygen was already known, yet phlogiston, the fire element, also played its part. Chlorine was still oxygenated hydrochloric acid; potash and lime were still elements. Invertebrate animals were divided into insects and reptiles; and in botany," he winds up, "we still counted stamens."

Research was obviously for Helmholtz an enjoyable task, and despite his expressed view that research should ideally be a means rather than an end, he seems to have taken the greatest pleasure in the actual performance of his investigations. But he could still keep in mind what was to him the fundamental aim of science: "to make the reasonless forces of nature subservient to the moral purposes of humanity."

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It is most wretched always to be using what has been attained, and never reach further for one's self.—Roger Bacon.

Photosynthetic Nitrogen Fixation by Blue-Green Algae

M. B. ALLEN

Dr. Allen received her training at the University of California, Berkeley, and at Columbia University. Since 1953 she has been associated with the laboratory of plant physiology of the department of soils and plant nutrition at the University of California. Prior to that, she spent 6 years at the Hopkins Marine Station, Stanford University, and 1 year at Washington University, St. Louis. During World War II she worked in radiochemistry and chemical engineering for the Manhattan Project. This article is based on a paper presented at the Conference on Solar Energy—the Scientific Basis that was held 31 Oct.–1 Nov. 1955 at Tucson, Ariz.

CONVERSION of molecular nitrogen into organic form by photosynthetic organisms is the most direct method of utilizing solar energy to increase the supply of nitrogen available for food and feed. This process is clearly of great theoretical importance and might have considerable practical value if effective means of utilizing nitrogen-fixing photosynthetic organisms could be devised. However, until quite recently little work was done on either the fundamental or the applied aspects of photosynthetic nitrogen fixation, for the organisms involved were considered to be slow-growing and difficult to handle in the laboratory. Recent results have shown, however, that members of one group of photosynthetic nitrogen-fixing organisms, the blue-green algae, grow under favorable conditions at a rate comparable to that of other rapidly growing plants; this points the way to possible applications of these algae (*1*).

The experiments of Schlösing and Laurent in 1892 (*2*) suggested the possibility that blue-green algae could obtain their nitrogen from the air, and the investigations of Beijerinck in 1902 (*3*) made the possibility into a likelihood, but there was for many years considerable doubt about the ability of the algae to fix molecular nitrogen, for the ability of some isolates to grow in media without added nitrogen might have been due to the activities of associated nitrogen-fixing bacteria. This question was finally resolved by the work of Drewes (*4*), Allison *et al.* (*5*), De (*6*), Bortels (*7*), and Fogg (*8*), who presented conclusive evidence for the fixation of molecular nitrogen by pure cultures of blue-green algae. In these studies, the rate of development of the algae was quite low, 0.3 to 2.0 grams (dry weight) of cell material per liter of culture medium being obtained in 20 to 60 days.

When studies of nitrogen-fixing blue-green algae were begun in our laboratory, a preliminary screening of the cultures available indicated that *Anabaena cylindrica* was a rapidly growing and conveniently handled representative of the group. Under proper conditions of nutrition and illumination, it has been possible to obtain a daily increment of 2.0 grams (dry weight) of cells of this alga per liter of culture medium, or 26 grams per square meter of illuminated surface. Less extensive studies with other nitrogen-fixing strains have indicated that this growth rate is not unusual and that it may be taken as typical of the growth of this type of alga under favorable conditions.

These high cell yields are possible only when an adequate nutrient medium is provided. The basic culture medium and the conditions for growth that have been used are similar to those which have given high cell yields of green algae (*9*). Like green algae and higher plants, the blue-green algae must be furnished with the macronutrient elements—carbon, nitrogen, phosphorus, potassium, sulfur, and magnesium—as well as micronutrient elements. However, the nutritional requirements of the blue-green algae have been found to differ in several respects from those of the green algae commonly studied (*1, 10*). Calcium is required in macro quantities, whereas *Chlorella* requires calcium only as a micronutrient (*10*). As shown in Fig. 1, calcium is needed whether the algae are fixing nitrogen or growing with nitrate as the nitrogen source. It had previously been suggested (*5*) that strontium could substitute for calcium in the nutrition of blue-green algae. However, Fig. 2, which illustrates the appearance of cultures with no calcium or strontium, with calcium added, and with strontium added, indicates that calcium cannot be replaced by strontium for the growth of *Anabaena*.

Molybdenum, a micronutrient metal that has

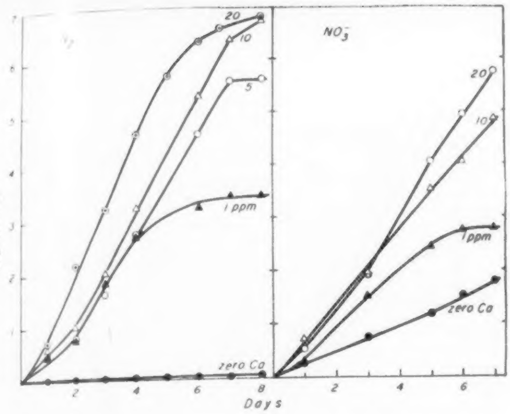

Fig. 1. Calcium requirement of *Anabaena cylindrica*. Light intensity, 7500 lux. Calcium concentrations in parts per million (ppm) are shown on the curves.

been implicated in nitrogen metabolism, is also required by blue-green algae in amounts greater than those needed by green algae such as *Chlorella* and *Scenedesmus* (*9–12*). Figure 3 shows the molybdenum requirement of *Anabaena cylindrica* growing with nitrate and with molecular nitrogen. In both cases, approximately 10 micrograms per liter is necessary for maximum growth of the algae, in contrast to the 0.1 microgram per liter required by *Scenedesmus* (*9*). The molybdenum requirement, like the calcium requirement, is specific. As shown in Fig. 4, molybdenum cannot be replaced by vanadium. Molybdenum appears to be needed by the algae only for nitrate reduction and nitrogen fixation (*12, 13*). As has previously been shown for *Scenedesmus* (*14*), molybdenum is not needed if the algae are given ammonia or urea as a source of nitrogen.

Two other growth requirements of the blue-green algae have no known parallel in the nutrients needed by green algae or higher green plants. Cobalt was reported to be necessary for algae of this group by Holm-Hansen, Gerloff, and Skoog (*15*), a finding that has been confirmed in this laboratory (*16*). Cobalt deficiency affects the pigmentation of the algae markedly, but it has only a relatively small effect on growth.

Sodium has been shown to be essential for growth of blue-green algae regardless of their potassium status (*10, 17*), whereas the beneficial effect of sodium on higher plants appears to be limited to a sparing action on their potassium requirement (*18*). Figure 5 illustrates the appearance of cultures of *Anabaena* with and without added sodium. Figure 6 shows that 5 to 10 milligrams of sodium per liter is required for optimal development of *Anabaena*. Sodium cannot be replaced by other alkali metals, as Fig. 7 shows.

Under favorable conditions, the growth of *Anabaena* proceeds at the same rate and to the same final density whether molecular or combined nitrogen is used as the nitrogen source, as is shown in Fig. 8. To obtain maximum growth rates with molecular nitrogen, the algae must be grown either in shaken culture or in a thin layer of liquid, so that the gas has free access to the cells.

Preliminary results indicate that nitrogen fixation by *Anabaena* differs from that of heterotrophic microorganisms such as *Azotobacter* (*19*) in that it is not prevented by the presence of combined nitrogen in the medium. As shown in Table 1, nitrogen was still fixed when high concentrations of nitrate were present in the culture solution (*12*). The supply of combined nitrogen was replenished daily, so that at no time were the cells in a medium that did not contain an excess of combined nitrogen. Little or no nitrogen was fixed in the presence of ammonia or urea, however—a finding that is in agreement with the close association of ammonia with nitrogen fixation that was established by Wilson and his collaborators as the result of experiments with *Azotobacter* and *Clostridium* (*19*).

The older literature contains statements that blue-green algae are adversely affected by high light intensities (*5*), a result that was difficult to reconcile with their frequent occurrence on walls or rocks exposed to full sunlight. It is probable that the earlier findings were the result of growing the algae under unfavorable conditions, for it has been found that, under conditions of adequate nutrition, the growth of *Anabaena* increases with increasing light intensity up to at least 16,000 lux, as shown in Fig. 9.

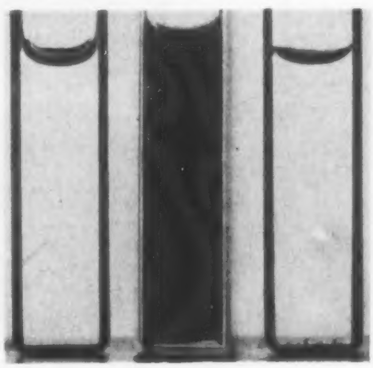

Fig. 2. Effect of calcium and strontium on growth of *Anabaena*. Seven-day cultures. Light intensity, 7500 lux. (Left) no calcium or strontium added; (center) 20 parts per million of calcium added; (right) 20 parts per million of strontium added.

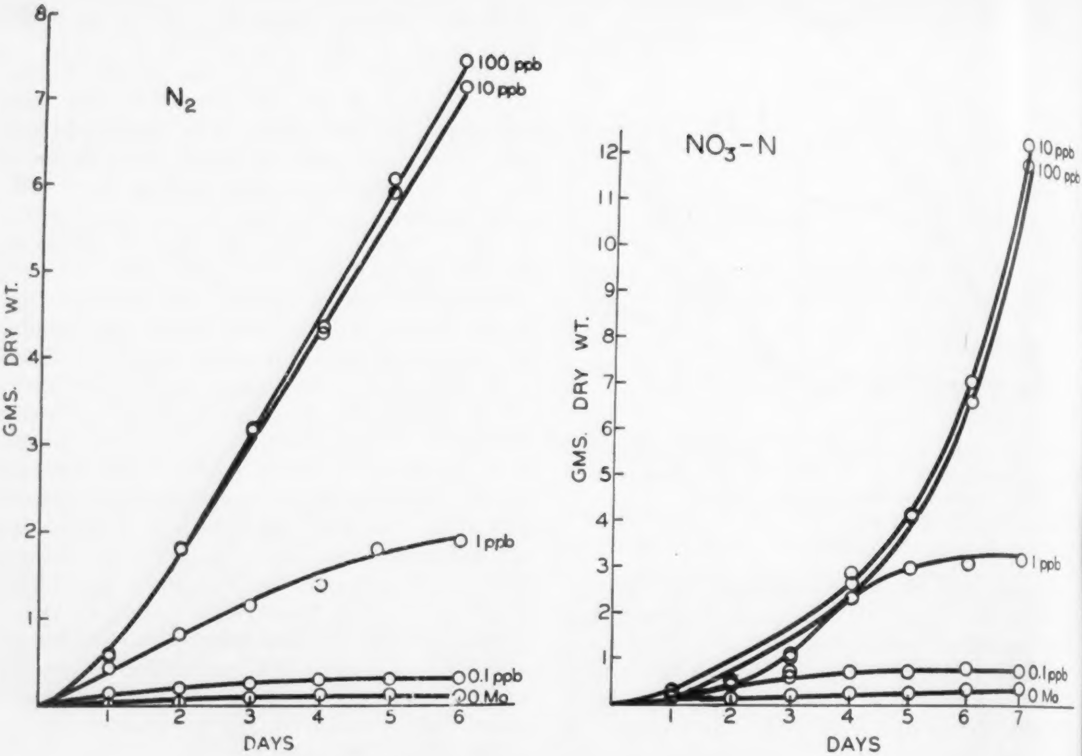

Fig. 3 Molybdenum requirement of *Anabaena* growing with molecular nitrogen (left) nitrate nitrogen (right). Light intensity, 16,000 lux.

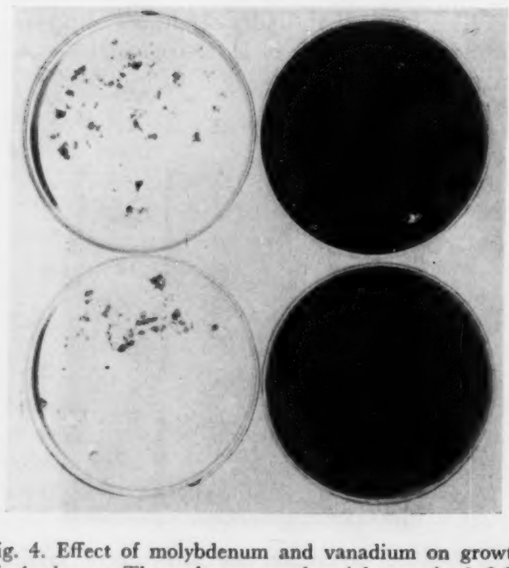

Fig. 4. Effect of molybdenum and vanadium on growth of *Anabaena*. The cultures on the right received 0.01 part per million of molybdenum and 0.01 part per million of vanadium; those on the left received 0.01 part per million of vanadium. Light intensity, 7500 lux.

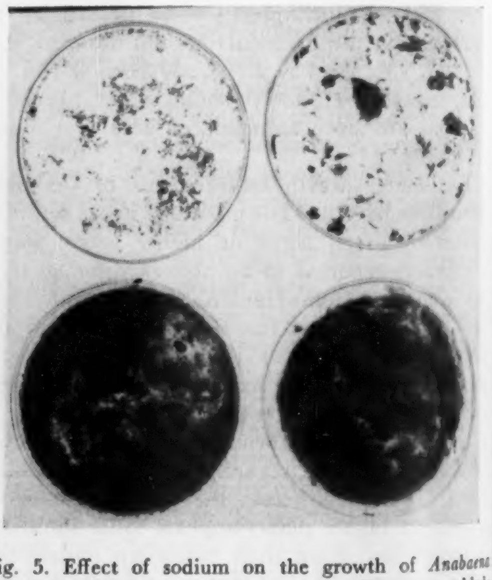

Fig. 5. Effect of sodium on the growth of *Anabaena cylindrica*. In the pale cultures, no sodium was added; in the dark cultures, 92 milligrams of sodium per liter was added. Molecular nitrogen was the source of nitrogen. Light intensity, 7500 lux.

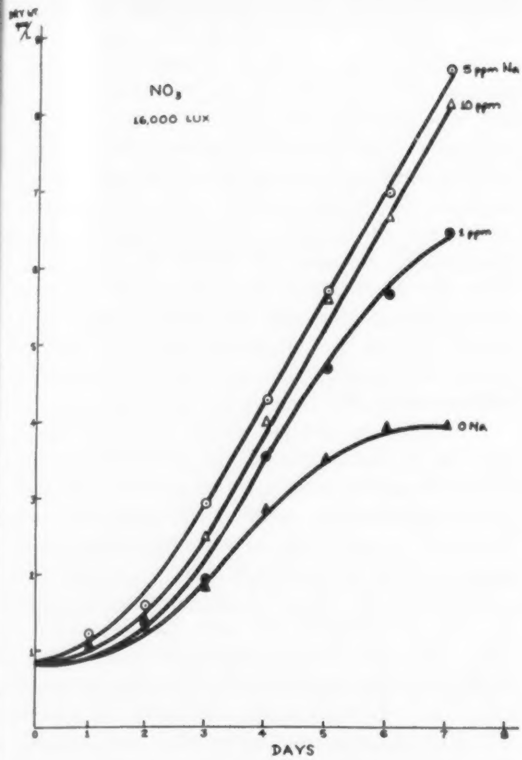

Fig. 6. Effect of sodium concentration on the growth of *Anabaena cylindrica*. Similar results were obtained with molecular nitrogen as the nitrogen source; 860 milligrams of potassium as KNO_3 were added per liter of nutrient solution.

Fig. 7. Failure of lithium, rubidium, and cesium to substitute for sodium in the growth of *Anabaena cylindrica.*

As has previously been found for green algae (*20*), photosynthesis is not the process that limits the growth of *Anabaena* at high light intensity. As shown in Fig. 10, growth was as rapid with 13 hours of illumination each day as with 24. This result implies that figures for growth under continuous illumination need not be greatly different from those expected if the sun is used as a source of light.

The blue-green algae are, as a group, more tolerant of moderately high temperatures than the green algae. Examination of 40 pure cultures of various blue-green algae isolated without any attempt to obtain heat-tolerant strains showed that all grew well at 35°C and that most developed normally at 40°C. These observations were made with the algae on agar slants and with carbon dioxide obtained from the air, a condition not favorable to the most rapid metabolism. Studies of thermophilic bacteria have shown that for these organisms growth at high temperatures is dependent on favorable conditions for metabolism (*21*). If these findings are considered to be generally applicable, it might be expected that the blue-green algae would grow at even higher temperatures under optimum culture conditions with an adequate carbon dioxide supply.

No marine nitrogen-fixing blue-green algae have as yet been isolated. Attempts to adapt *Anabaena* to sea water have met with little success, as might have been predicted from the failure of thousands of years of evolution to produce a marine nitrogen-

Fig. 8. Growth of *Anabaena* with molecular and combined nitrogen.

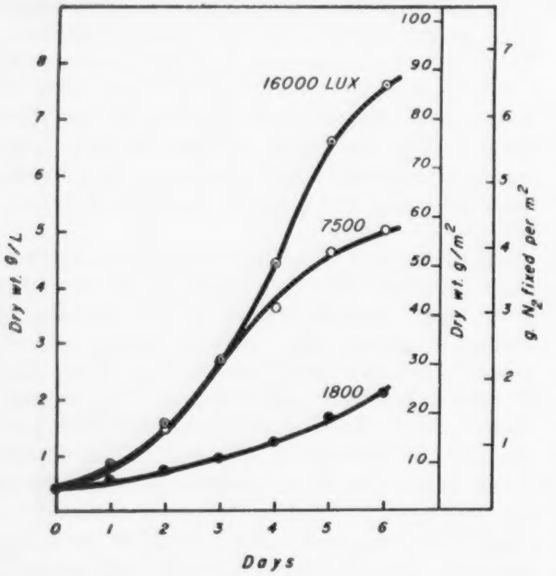

Fig. 9. Effect of light intensity on growth of *Anabaena*; molecular nitrogen was the nitrogen source.

fixing alga. However, although it will not grow in undiluted sea water, *Anabaena* has been found to be fairly tolerant of salt. Normal growth occurs in media containing up to 1.5-percent sodium chloride, and growth takes place after a long lag in 2-percent salt.

The nitrogen-fixing blue-green algae thus appear, not as fragile and difficult-to-handle creatures, but as adaptable organisms capable of rapid growth and nitrogen fixation under favorable conditions. It is of interest to compare the yields of blue-green algae with those obtained with green algae and higher plants. Table 2 shows the yields obtained with tomatoes (*22*) and potatoes (*23*) grown in nutrient solutions—that is, grown under conditions more nearly comparable to those of algae cultured in the laboratory than are field crops. Comparison of Table 2 with Table 3, which gives similar yield figures for representative green and blue-green algae, shows that the amount of cell material produced by photosynthesis per month is of the same order of magnitude for all three types of plant. The algae, however, have a much greater percentage of nitrogen content than the higher plants (*24*). In order to obtain the high yield of *Scenedesmus* shown in the table, a nitrogen input in a combined form of 780 pounds per acre, per month would be required, whereas *Anabaena* would fix gaseous nitrogen in an organic form equivalent to 480 pounds per acre, per month.

These figures are, of course, extrapolations of laboratory results, and as such are somewhat speculative. However, even a fraction of this increase in combined nitrogen under field conditions would represent a large gain of nitrogen compared with that fixed by other biological agents under natural conditions. *Azotobacter* is reported to fix up to 40 pounds of nitrogen per acre, per year in fertile soil, and the legume-rhizobium combination to contribute approximately 200 pounds per acre, per crop (*25*). It has therefore been of interest to see whether nitrogen fixation by blue-green algae may be of importance in natural environments where these algae develop abundantly.

The blue-green algae that grow endophytically in aquatic plants such as *Azolla* have been shown to be capable of fixing molecular nitrogen (*4*), and *Azolla* has been grown in a medium without added nitrogen, presumably at the expense of nitrogen fixed by its symbiotic algae (*26*). However, much more potential importance is attached to the blue-green algae that develop in great masses in the rice fields. These have been shown to include nitrogen-fixing species (*6*), and a beneficial effect of the algae on rice has been indicated (*27*).

Table 1. Fixation of molecular nitrogen by *Anabaena cylindrica* in the presence of combined nitrogen. The nitrogen figures are in milligrams per liter. Medium and culture conditions were the same as those described by Arnon and Allen (*1*).

Day	Nitrate			Ammonia			Urea		
	Total N added	Total N in system	N fixed	Total N added	Total N in system	N fixed	Total N added	Total N in system	N fixed
2	280	303	23						
3	420	490	70						
4	560	656	106	420	436	36	420	437	17
5	840	1030	190	700	704	4	700	756	56
6	1120	1145	325	980	990	10	980	970	0
7	1400	1900	500	1260	1360	100	1400	1430	30

Table 2. Growth of tomatoes (*22*) and potatoes (*23*) under optimal culture conditions.

Culture	Tomatoes			Potatoes		
	Yield of fruit in greenhouse culture ($lb/25\ ft^2$ 6 mo)	Calculated yield (ton/mo acre)		Yield obtained in outdoor culture ($lb/25\ ft^2$ 6 mo)	Calculated yield (ton/mo acre)	
		fresh wt.	dry wt.		fresh wt.	dry wt.
Soil	238	34	2	69	15	3
Nutrient solution	357	52	3	106	23	3

Table 3. Growth (dry wt. basis) and nitrogen economy of representative green and blue-green algae.

Alga	N source	Density at Harvest		Highest yield obtained (g/m^2 24 hr)	Calculated yield (ton/acre mo)	Calculated N balance* (lb/acre mo)	
		(g/lit)	(g/m^2)			fixed	consumed
Scenedesmus obliquus	NO_3^-	13.9	158.	56.8	7.8		780†
Anabaena cylindrica	N_2	7.6	86.5	25.0	3.4	480‡	

* Computed on basis of 7 percent N of dry wt. of *Anabaena* and 5 of *Scenedesmus*. † Corresponds to 3700 lb of ammonium sulfate. ‡ Corresponds to 2300 lb of ammonium sulfate.

Recent studies (*28*) have shown that the nitrogen fixed by blue-green algae is available to rice plants and that it is possible to grow rice with no nitrogen other than that fixed from the air by algae growing together with the rice plants. Figure 11 shows the results of such an experiment. Both sets of cultures contained a nutrient medium that was complete except for the absence of nitrogen. In the beakers that had been inoculated with *Anabaena*, rice plants grew at the expense of atmospheric nitrogen, while in the beakers without algae the rice died as soon as the nitrogen reserves of the seed had been exhausted. In Table 4 are presented the results of a similar experiment with pure culture rice plants and *Anabaena*. Although the conditions necessary for pure culture experiments were not optimal for development of rice, the differential between plants without nitrogen and those receiving nitrogen fixed by *Anabaena* is evident. It may be noted that both the greenhouse and the pure culture experiments represent more stringent conditions than would be encountered in the field, where nitrogen fixed by blue-green algae growing 1 year would be available to the next year's crop. In the experimental tests, the rice was dependent on nitrogen supplied by algae developing together with the rice plants.

It thus appears that blue-green algae may play an important role in maintaining the fertility of rice fields, and the results of experiments on a larger scale to determine how the nitrogen fixation

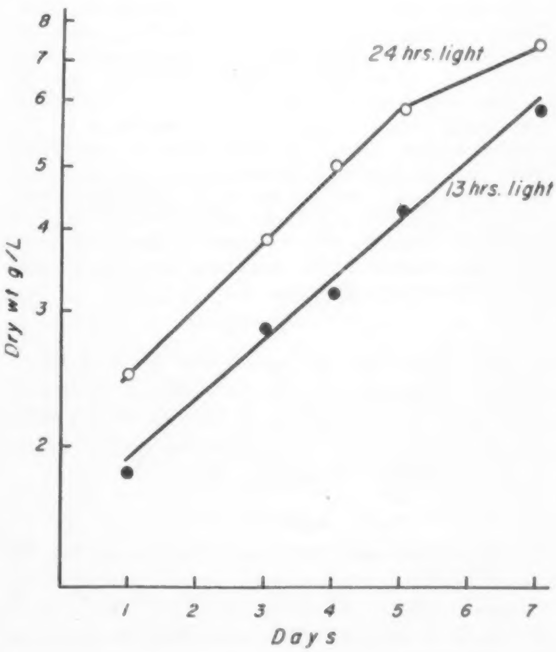

Fig. 10. Comparison of growth of *Anabaena* in continuous and intermittent light. Light intensity, 16,000 lux; molecular nitrogen was the nitrogen source. The upper curve shows growth in continuous light; the lower curve shows growth with 13 hours of light and 11 hours of darkness each day.

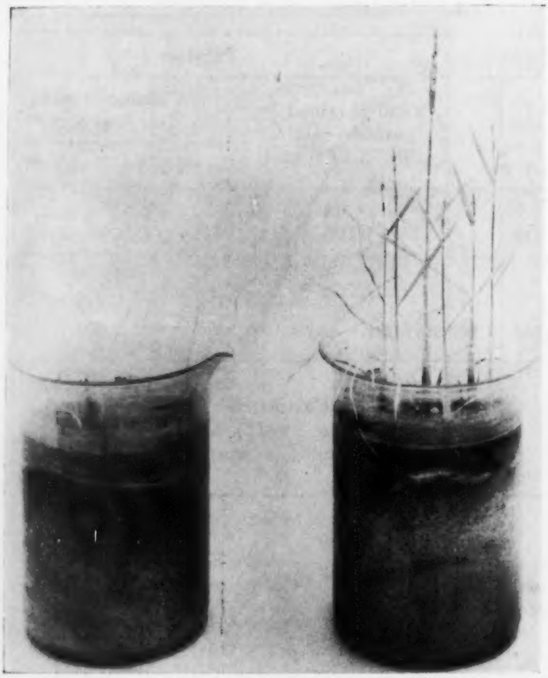

Fig. 11. Rice plants grown at the expense of molecular nitrogen by culture with *Anabaena cylindrica*. The plants are in sand culture in 2-liter beakers. Culture medium: $MgSO_4$, $0.002M$; $CaCl_2$, $0.003M$; Na_2HPO_4, $0.001M$; KH_2PO_4, $0.001M$; and micronutrient mixture (*1*). Four beakers received no further addition, and four were inoculated with *Anabaena cylindrica*. (Left) A representative control beaker; (right) a representative of an inoculated beaker. The plants were grown in the greenhouse from 23 July to 2 October, when the dry weight and the nitrogen content of the plants were determined. Average figures were as follows: uninoculated, 0.19 gram dry weight containing 0.53 milligrams of nitrogen; inoculated with *Anabaena*, 2.00 grams dry weight containing 12.59 milligrams of nitrogen.

by these algae may be put to best use will be of interest. Exploration of the possibility of fertilizing other crops by a preliminary flooding of the field and growth of a mass of nitrogen-fixing blue-green algae may also be envisaged (*28*).

Table 4. Growth of pure culture rice plants with *Anabaena cylindrica*. Seeds were sterilized with mercuric chloride, germinated under aseptic conditions, and planted in large tubes containing sterile sand and the following culture medium: $MgSO_4$, $0.001M$; $CaCl_2$, $0.001M$; NaH_2PO_4, $0.001M$; K_2HPO_4, $0.001M$; *Anabaena* micronutrient mixture (*1*), 10 ml/lit. Six plants were used per tube. Two tubes received inoculum of *Anabaena cylindrica*, two received 1.5 ml of 1 *M* KNO_3, and two received no further additions. Tubes incubated in lighted box on a schedule of 16 hr of light and 8 hr of darkness. Growth was somewhat inhibited by high humidity in tubes. The plants were grown for 3 months, then harvested; the dry weight and nitrogen content of plants were determined. The weights per tube are given.

Conditions	Dry weight of plants (g)	N in plants (mg)
No added nitrogen	1.0	3.2
No added nitrogen + *Anabaena*	2.3	12.0
KNO_3 added	1.9	23.6

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ASSOCIATION AFFAIRS

General Chairman for AAAS Meeting

The appointment of local committees to assist with phases of the 123rd annual meeting of the AAAS began auspiciously when Eugene Holman, chairman of the board and chief executive officer of the Standard Oil Company of New Jersey, accepted appointment as general chairman of the New York meeting. Holman, whose undergraduate and graduate training in petroleum geology was received at Simmons University, now Hardin-Simmons University, and the University of Texas, respectively, has been associated with Standard Oil Company of New Jersey since 1929, serving as president 1944–53; prior to that he was with an oil exploration party in Cuba, the U.S. Geological Survey, and the Humble Oil and Refining Company. In World War I, he served as an aerial photographer in the Army Signal Corps.

It is anticipated that the first committee which Holman will form will be the Exhibits Committee. This committee need not concern itself with assisting in the sale of conventional boothspace, since at this time, 6 months in advance of the meeting, nearly all of the 74 booths on the Hotel Statler mezzanine, adjacent to the ballroom, have been assigned. The Exhibits Committee will consider the further development of panel exhibits by large industries, around the mezzanine well, or upper lobby, of the hotel. It is indicated that these displays of some of the latest technologic accomplishments of large firms will make the Association's 1956 Annual Exposition of Science and Industry one of the largest and most diversified since its beginnings in 1924.

Hotel Headquarters and Housing, New York Meeting

The preliminary announcement of the seventh New York Meeting, 26–31 Dec., of the American Association for the Advancement of Science [*Science* **123**, 947 (1956); *Sci. Monthly* **83**, 48 (1956)], although it named the Statler as AAAS headquarters hotel, the New Yorker as headquarters for the Entomological Society of America, and the Sheraton-McAlpin as headquarters for the science teaching societies, was principally concerned with the programs of the 1956 meeting—as planned by all 18 AAAS sections and by some 44 participating societies (exclusive of another 40 organizations which will participate as official cosponsors of appropriate sessions). A list of the headquarters for each section and participating organization is appended—it is an obvious convenience for each person attending the meeting to have this information before he applies for room reservations. However, since all five "Penn Zone" hotels are within a block of Pennsylvania Station—with which three of them are connected by tunnels, and thus with each other—one hotel is almost as convenient as another.

The center of the meeting will be the Hotel Statler and here will be located the AAAS Main Registration-Information Center, the Visible Directory of Registrants, the AAAS Office, AAAS Press Room, AAAS Science Theatre, and the Annual Exposition of Science and Industry. The Statler's large ballroom and adjacent rooms will be the site of the AAAS-sponsored general symposium, *Moving Frontiers of Science,* the Council meeting and other business sessions of the Association, the AAAS Presidential Address and Reception, the special evening events, and the AAAS Smoker. With a very few exceptions, all sessions will be in the numerous public rooms of the Statler and the other Penn Zone hotels. It follows that the meeting will be a particularly convenient one in all respects.

Housing

Beginning with this issue, the advertising section of *The Scientific Monthly* will carry, at frequent intervals, page announcements of hotel sleeping accommodations and their current rate schedules, together with a coupon which should be filled out and sent, *not* to any hotel directly, but to the AAAS Housing Bureau in New York. (Members of the American Astronomical Society, however, wishing rooms in uptown hotels, such as the Alden, should correspond directly with the Hayden Planetarium.)

All applications for hotel rooms will be filled in the order of their receipt. Those who apply early are assured of the hotel of their first choice if the stated desired and maximum rates are within the limits of the printed rate schedules. In New York's Penn Zone there is an adequate supply of rooms at a wide range of rates. It would be well to consider, however, that, as in any city, the supply of single rooms at minimum rates is relatively limited and that higher priced single rooms and double rooms for single occupancy are more plentiful. Thus, it is suggested that the *maximum rate,* which you do not wish to exceed, and your *desired rate* both be stated on your coupon. Room expenses

usually can be reduced substantially if rooms are shared by two persons or if suites are shared by three or more persons. Also, upon request, most hotels will place comfortable rollaway beds in rooms or suites at $2.50 or $3.00 per night.

Registration

Both the technical or program sessions and the special sessions are open to all interested persons. Although registration for these is not mandatory, it is expected that all who attend will wish to pay the AAAS registration fee of $3.00 and thus contribute a proportionate share of the heavy expenses of the meeting. Each registrant receives the book-size General Program-Directory (a valuable reference on all AAAS activities), convention literature, listing in the Visible Directory of Registrants, and a Convention Badge, which insures all privileges of the meeting. The badge *is* required for admission to the large-scale exhibits, the AAAS Science Theatre, the Presidential Address and Reception, and the AAAS Smoker; refreshments are served at the last two events. It is planned to distribute to registrants a limited number of free radio broadcast tickets on the first days of the meeting; usually the Empire State Building's observation tower and other points of interest to which admission is charged grant discounts to registrants.

Advance registration has some decided advantages: delay at the registration desks upon arrival is eliminated; the General Program-Directory, which is sent by first class mail early in December, enables one, at leisure, to determine which events and sessions he particularly does not wish to overlook; and one's name is posted in the Visible Directory of Registrants as the meeting opens (hotel room can be added to the slip later by the registrant himself).

An announcement on advance registration and a coupon for this will also be found in the advertising section of this issue and at intervals thereafter.

Penn Zone Hotels

Note: Societies are grouped in the same sequence of disciplines as the letters of the AAAS sections.

Statler (2200 rooms), 32 and 33 Sts. and Seventh Ave.: AAAS; Press; Exhibits; AAAS Sections C–Chemistry, F–Zoological Sciences, G–Botanical Sciences, M–Engineering, N–Medical Sciences, Nd–Dentistry, Np–Pharmacy, and P–Industrial Science; AAAS-Gordon Research Conferences, Alpha Chi Sigma; American Society of Zoologists, Herpetologists League, International Union for the Study of Social Insects, New York Zoological Society, Society of Systematic Zoology, Society of Vertebrate Paleontology; American Society of Naturalists, Ecological Society of America, Genetics Society of America, Society for the Study of Evolution, Society of General Physiologists; American Society of Plant Physiologists, Botanical Society of America, Torrey Botanical Club; Engineering Manpower Commission; Alpha Epsilon Delta, American Association of Hospital Consultants, American Medical Association Committee on Cosmetics, American Physiological Society, American Psychiatric Association; American College of Dentists, American Dental Association, International Association for Dental Research; American Association of Colleges of Pharmacy, American College of Apothecaries, American Pharmaceutical Association, Scientific Section, American Society of Hospital Pharmacists; American Association of Scientific Workers, Conference on Scientific Manpower, National Academy of Sciences–National Research Council, National Association of Science Writers, National Science Foundation, New York Academy of Sciences, Scientific Manpower Commission, Scientific Research Society of America, Sigma Delta Epsilon, Society of the Sigma Xi, United Chapters of Phi Beta Kappa.

Governor Clinton (450 rooms), 31 St. and Seventh Ave.; AAAS Sections A–Mathematics and L–History and Philosophy of Science; Association for Computing Machinery, Society for Industrial and Applied Mathematics; American Philosophical Association, History of Science Society, Philosophy of Science Association, Society for the Advancement of General Systems Theory; American Documentation Institute, Conference on Scientific Editorial Problems, National Bureau of Standards.

Sheraton-McAlpin (1500 rooms), 33 and 34 Sts. and Broadway: AAAS Sections H–Anthropology, I–Psychology, K–Social and Economic Sciences, and Q–Education; National Association of Biology Teachers; American Institute of Human Paleontology; American Political Science Association, American Sociological Society, National Academy of Economics and Political Science, Pi Gamma Mu, Society for the Advancement of Criminology; AAAS Cooperative Committee on the Teaching of Science and Mathematics, American Educational Research Association, International Council for Exceptional Children, National Association for Gifted Children, National Association for Research in Science Teaching, National Science Teachers Association; Academy Conference, American Nature Study Society.

Martinique (350 rooms), 32 St. and Broadway: AAAS Sections B–Physics, E–Geology and Geography, and O–Agriculture; American Meteorologi-

al Society, Sigma Pi Sigma; Association of American Geographers, Geological Society of America, National Geographic Society, National Speleological Society; American Society of Range Management; American Geophysical Union.

New Yorker (2200 rooms), 34 and 35 Sts. and Eighth Ave.: Entomological Society of America.

Uptown Hotels

Alden (600 rooms), 82 St. and Central Park West: AAAS Section D–Astronomy, American Astronomical Society.

Edison (869 rooms), 228 W. 47 St.: also recommended for astronomers.

BOOK REVIEWS

Science and the Course of History. Pasqual Jordan. Translated by Ralph Manheim. Yale University Press, New Haven, Conn.; Oxford University Press, London, 1955. x + 139 pp. $2.50.

This book is made up of radio talks delivered during a period of 3 years for Radio Bremen by the well-known quantum physicist, Pascual Jordan. The major theme is that scientific knowledge cannot be considered as a finished product but must be seen as part of a historical development. A secondary theme is that the history of man loses its quality of a series of "scattered, disparate events" and "becomes a unified coherent process if we look on the gradual advance of man's knowledge as a basic theme of historical development." Jordan holds that "our own day-to-day life is shaped by what the philosophers and scientists of the last two centuries have thought and expanded"; thus it is a necessary conclusion that "the ideas which are taking form today, the knowledge which is being acquired in our time, will be the crucial factors in tomorrow's decisions." In order to gain some idea "of the momentous changes that the future has in store for us," we must be aware "of the headlong intellectual transformations taking place today."

In presenting this significant and challenging thesis, Jordan addresses himself primarily to three basic issues. The first of these implies an "age of transition," an expression used to indicate that we find ourselves in a temporal setting in which classical physics has collapsed and the implications of the new physics have not yet been fully comprehended. Thus we find torments, difficulties, crises, and "a temporary, makeshift quality about all our undertakings, possessions, and experiences." These are the symptoms of change. Briefly presenting some of the major features of the rise of modern physics, Jordan expounds the thesis that science quickly weathers its so-called "crises," but that society or man does not.

The most fascinating part of this section of the book is the very illuminating discussion of science and technology. Jordan presents clearly and dramatically the failure of technology to solve the problems of society. It used to be thought that technologic progress would "bring with it a moral improvement, an ethical development of man." The reason is that many thinkers supposed that "technology, by fulfilling man's desires, would relax human tensions and conflicts" because "only poverty and hardship make men evil." Our experience to date has been the contrary; "far from putting an end to all conflicts by fullfilling the wishes of all men," technologic advances "brutally intensify these conflicts."

The second basic issue that Jordan discusses is at once removed from science applied to this world; he takes us into the realms of "cosmic space" and its exploration by scientists. Presenting the growth of our knowledge of stars and galaxies and the history of the earth and the universe, Jordan triumphantly examines the "finiteness of the cosmos" —triumphantly in the sense that astronomers now can "consider problems which in the last century had seemed totally inaccessible." Concluding with "a picture of cosmic development which we can only describe in the words: *creation out of nothingness,"* this section ends with a harmonious view that makes the imaginings of philosophers seem paltry things by comparison.

The third and final issue is life itself: first, the Darwinian attack on the fixity of species; then, the Mendelian view of inheritance and variation (linked skillfully by the author to the parallel development of concepts of discreteness in physical science). Jordan presents the view that life cannot be considered exclusively from a mechanistic point of view. Finally, there are speculations on the beginning of life and the possibility that life may exist on other worlds than ours.

The first section of this book is challenging and dramatic, presenting many of the fundamental issues of science and man in a perceptive way that will stimulate every reader to reflect on himself and his ideas in relation to the history of scientific

thought. The second section is more speculative, as perhaps its "cosmic" subject demands, and although less challenging than the previous portion it, too, bears serious attention. In the third and concluding section, however, one cannot escape the feeling that the author is writing of biology as a quantum physicist, in the end reducing all problems in biology to mere chemistry and physics. Physical, rather than biological, scientists seem today too concerned with "big questions" like "the nature of life." I, for one, would have preferred to have Jordan conclude this attractive book with some topic in which his scientific training and personal insight might more appropriately and fruitfully have been employed.

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Celebrated American Caves. Charles E. Mohr and Howard N. Sloane. Rutgers University Press, New Brunswick, N.J., 1955. xii + 339 pp. Illus. $5.

The preparation and publication of this volume was sponsored by the National Speleological Society. This society, whose purpose is to foster interest in the knowledge to be gained from cave exploration and to protect from thoughtless vandalism the natural features of the underground world, has published the book as one means of accomplishing its objectives.

Fifteen qualified students have furnished the stimulating material. Following a foreword by Alexander Wetmore and a brief editor's note, the book is divided into the following chapters: "Introducing the American underworld," by William E. Davies; "The Devil's Sinkhole," by Patrick J. White; "Cave of the Vampires," by Charles E. Mohr; "Assault on Schoolhouse," by Ida V. Sawtelle; "The impossible pit," by Roger W. Brucker; "The miners' bathtub," by William R. Halliday; "Mammoth Cave's underground wilderness," by Henry W. Lix; "Medicine, miners and mummies," by Howard N. Sloane; "The Valley of Virginia," by Davies; "Carlsbad Caverns," by T. Homer Black; "The death of Floyd Collins," by Brucker; "Bones and a railway," by G. Nicholas; "Earliest Americans," by Frank C. Hibben; "Hidden skeletons of the Mother Lode," by Halliday; "Bats and bombs" and ". . . bands," by Mohr; "The one who cries," by Sloane; "The idol of the cave," by M. R. Harrington; "No eyes in the darkness," by William Bridges; "Ozark cave life," by Mohr; "The leather man," by Leroy W. Foote; "The cave in rock murderers," by George F. Jackson; "Mark Twain Cave," by Sloane; and "Lost footprints," by Jackson.

The various chapters are well illustrated. An interesting map of the United States showing the cavern areas is included.

Viral and Rickettsial Diseases of the Skin, Eye and Mucous Membranes of Man. Harvey Blank and Geoffrey Rake. Little, Brown, Boston–Toronto, 1955. xiv + 285 pp. Illus. + plates. $8.50.

This book is designed to serve clinicians who are interested in dermatology and scientists who are interested in the viral agents involved in the etiology of skin diseases. To write a book covering such a wide field is a very difficult task, but with their excellent experience in viral and rickettsial infections involving the skin, eye, and mucous membranes, Blank and Rake have succeeded in producing an extensive study of this subject. It would be difficult to improve on some of the chapters, for instance, the one on smallpox, cowpox, and vaccinia. Smoothness of style and simplicity of presentation enable a student to grasp immediately the essential facts involved in the clinical features, pathology, and etiology of these illnesses.

The chapter on the common cold is the least informative; but, in the present stage of confused knowledge, it is difficult to know how a concise and pertinent summary could be written on this subject. The chapter on warts is remarkably extensive; I have learned more about these growths from this book than from any other source in the relevant literature.

Since publication of this book 1 year ago, more recent data have become available on certain of the subjects mentioned—for instance, agammaglobulinemia and susceptibility to generalized vaccinia—which should be included in the next edition.

In brief, the book can be recommended warmly to medical students who are interested in this particular field of disease or who intend to make dermatology the subject of postgraduate study. It should also be valuable to specialists who may be too busy to keep up with all the current literature of skin diseases; and last, but not least, it should be read by virologists and scientists who wish to pursue investigations on these diseases, about which relatively little is known.

Hilary Koprowski

Lederle Laboratories,
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The Navajos. Ruth M. Underhill. University of Oklahoma Press, Norman, 1956. xvi + 299 pp. Plates + illus. $4.50.

In *The Course of Empire*, DeVoto complained that historians wrote too little about the American Indian and took the white point of view, while anthropologists slighted history in favor of ethnography and aboriginal tradition. Ruth Underhill's *The Navajos* is the 43rd publication in "The Civilization of the American Indian" series of the University of Oklahoma Press, some of the volumes of which DeVoto himself cited. This most recent volume would, I think, have pleased him. Written by an anthropologist who sees clearly both Indian and non-Indian points of view, it is a history, not an ethnography, which blends archeology, folklore, ethnology, and conventional historical materials (primary and secondary) in a cleanly written, smooth-flowing narrative. Underhill's own *Here Come the Navajo!* and *Red Man's America* are precursors of the present work in their historical orientation, but the style and smooth integration of *The Navajos* surpass them.

Athabaskan speakers, the Navajos, like the Apaches, derive ultimately from the Athabaskan homeland in Canada. Arriving in the Southwest in about A.D. 1100 as hunters and gatherers, they acquired agriculture from the Pueblo Indians and herding from the Spaniards as well as other items of culture too numerous to mention from these and Anglo-American sources. Much of what they took they modified, borrowing gladly from all available sources, resisting change only when it was enforced by a dominant group. Each technical change resulted in an expansion of population and territory. They judiciously alternated trading, intermarriage, and raiding in their relations with Indian and Spanish neighbors, until they were taken into captivity under U.S. control (1864–68) and pacified. Further expansion of tribe, land, and herds followed; but today population increases, land is held constant, and livestock has been markedly reduced by the Indian Service, beginning in the 1930's, in response to the overgrazing of the reservation. Today the 75,000 Navajos are our largest tribe, on our largest reservation, but less than half the tribe can be supported by farming and herding. The lack of education and of stable employment opportunities creates a sizable problem for the future. These are some of the facts that Underhill sets forth.

Criticisms of her presentation can be made. The book frequently fails to deal with the probable transformations of Navajo social life which must have accompanied technologic change. It oversimplifies land accessions and cessions. It does a poorer job on the years from 1933 to the present than on earlier periods: it underemphasizes the anguished Navajo reaction to livestock reduction, seems to accept state, rather than federal, control of Indian affairs as necessary and desirable; and, although realistic in its evaluation of current problems, it is more optimistic for the future than I can be. But it remains a fine presentation of Navajo history. The nonspecialist will be fascinated, and the specialist will be grateful for the many facts, some familiar, some not, assembled, documented, and integrated here. One can only wish for more works of this quality from Underhill and from others like her, to inform the public and to assist her colleagues by providing the historical perspectives so badly needed in much current anthropological research.

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Chemical Calculations. H. V. Anderson. McGraw-Hill, New York, ed. 6, 1955. viii + 305 pp. Illus. $4.75.

This is an elementary book, designed to guide the student in a common-sense method of solving chemical calculations, and in this it is successful. A variety of chemical calculations is dealt with, ranging from the conversion of pounds to grams on the one hand, to the degree of hydrolysis in a salt solution or the balancing of a redox equation on the other. The subject matter of the book is divided into 18 chapters, each dealing with one type of calculation by means of a general discussion, worked examples, and a set of problems.

This book will be of most value to those who are commencing an intensive study of chemistry, and such students should find the chapter on the language of chemistry most helpful. Such information is all too often assumed by authors of books of problems. A pleasing feature is the space devoted to nonarithmetical calculations, such as the balancing of redox and other equations. Such matters are just as much of a hurdle to junior students as, say, acidimetry calculations, and here they are well dealt with.

It is a pity, however, that in the chapter on "Oxidation and reduction" the author has seen fit to use the somewhat overworked omnibus term *valence* when he describes "oxidation number" as

"valence number." This may perhaps create confusion in the student's mind about the type of linkage to be found in a radical. Although the problems at the end of the chapter are quite satisfactory, there is a lack of a set of general problems, which could well be placed at the end of the book. Such a set could provide problems where the solution requires the use of two or more of the methods discussed in the earlier chapters and would help the student to bridge the gap between elementary and actual operations.

Nevertheless this book can be confidently recommended to those who have difficulty with the solution of elementary chemical calculations.

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The Thirteen Books of Euclid's Elements. 3 vols. Translated from the text of Heiberg with introduction and commentary by Thomas L. Heath. Dover, New York, ed. 2, rev. with additions, 1956. 432 pp.; 436 pp.; 546 pp. Paper, $5.85 the set.

The definitive English edition of this book, which was first brought out in 1908 and revised with additions in 1925, includes an introduction and commentary by the translator that covers a lot of territory: Euclid in Arabia, Hilbert, the first trace of the confusion between the mathematician's Euclid and Euclid of Megara, the first known definition of a point, the views of Schopenhauer and Bertrand Russell on an apparent use of motion in the fourth axiom—and so on, from Pythagoras through the first quarter of the 20th century.

Atlas of Paleogeographic Maps of North America. Charles Schuchert. Wiley, New York; Chapman & Hall, London, 1955. xi + 177 pp. Illus. $4.75.

To those of us who knew Charles Schuchert, it is a pleasure to see collected on one cover 84 of his paleogeographic maps. Schuchert never finished these maps to the point that he would publish them but kept them up to date so that when he died in 1942 they were as complete as he could make them. It is unfortunate that 12 years elapsed before they were published; they contain no added information since then. However, if they were brought up to date, the work would not represent Schuchert. They show his ideas of paleogeography from the Basal Waucoban (Lower Cambrian) up to and including the Pleistocene (Highest Cenozoic) in 84 maps, 7 by 9½ inches each.

E. WILLARD BERRY
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Geology: Principles and Processes. William H. Emmons, George A. Thiel, Clinton R. Stauffer, and Ira S. Allison. McGraw-Hill, New York-London, ed. 4, 1955. vi + 638 pp. Illus. $6.50.

Here is what might be considered a typical American textbook, efficiently written, factually complete, technically accurate, and profusely illustrated with pertinent photographs, understandable diagrams, and simple tables. On the whole, the exposition is clear and should be understood quickly by the average reader. It is a book to which one would go for descriptive information or use as a textbook for introducing a new subject. It is not a book whose reading becomes a pure pleasure for the neophyte or for the professional. It lacks the realism and critical spirit of synthesis that adds warmth and perspective to a subject, as is the case, for example, in Swinnerton's *The Earth beneath Us*. This is in no way a reflection on the quality of the book, which is excellent, but the book does illustrate a rather cold, orderly, precise, and descriptive presentation of the present status of a science.

This fourth edition of a well-known and excellent introductory American textbook is a considerably revised version of the third edition, and its format has been completely changed. The text has been expanded with complete revision and reorganization of certain sections, although the major plan of presentation is essentially unchanged. The revision has been made for the benefit of students desiring a cultural course in geology, but at the same time it offers those preparing for a major in the earth sciences a thorough grounding in the basic elements of geology.

Additions to the fourth edition include expansion of the scope and methods of geology, extensive revision of the structure of matter, and composition of minerals and rocks, new chapters on the gross features of the earth and on weathering and soils, and expansion of the discussion on work of the wind, glaciers and lakes, swamps and marshes. There are now two chapters on the oceans, and the discussion of earthquakes is placed with the nature of the interior of the earth. The chapters on moun-

tains and diastrophism have also been expanded, and more data on the nonmetals have been incorporated in the chapter on mineral resources. The other chapters show minor changes. The appendixes on maps and map symbols are unchanged. Slight revisions appear in the appendix on geologic time. One might ask here why a chapter on the history of development of geologic thought would not be appropriate in an introductory text.

There are 31 more figures in this edition than in the third. Many new photographs have been used in lieu of previous illustrations, and some of the line drawings have been revised and enlarged. Although the illustrations in the third edition were good, those in this edition are even better, and the authors have done well in selecting new localities as examples of geologic features. The new format is a considerable improvement, but I would like to raise the question of why, in view of frequent revisions and the high cost of textbooks and scientific books, it is deemed necessary to use heavy expensive paper, large type sizes, and wide margins and to leave large blank areas on many pages. Surely with careful editing the costs of scientific books could be reduced appreciably with no loss in content.

H. R. GAULT

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Books Reviewed in SCIENCE

1 June

Reflections of a Physicist, P. W. Bridgman (Philosophical Library). Reviewed by A. Mercier.

Physiologie der Zelle, J. Haas (Borntraeger). Reviewed by H. Ris.

Ergebnisse des Medizinischen Grundlagenforschung, K. Fr. Bauer (Thieme).

International Review of Cytology, vol. IV, G. H. Bourne and J. F. Danielli, Eds. (Academic Press). Reviewed by B. P. Kaufman.

Yearbook of Anthropology, 1955, vol. I, W. L. Thomas, Jr., Ed. (Wenner-Gren Foundation for Anthropological Research). Reviewed by S. H. Posinsky.

8 June

Blood Group Substances, E. A. Kabat (Academic Press). Reviewed by I. Asimov.

Louisiana Birds, G. H. Lowery, Jr. (Louisiana State University Press). Reviewed by A. Wolfson.

Advances in Veterinary Science, vol. II, C. A. Brandly and E. L. Jungherr (Academic Press). Reviewed by L. N. Loomis.

Comparative Endocrinology of Vertebrates, pt. I, I. C. Jones and P. Eckstein, Eds. (Cambridge University Press). Reviewed by D. Price.

Guide Pratique de Mycologie Médicale, J. Doudert (Masson). Reviewed by R. M. Page.

Cancer of the Lung, M. B. Rosenblatt and J. R. Lisa (Oxford University Press). Reviewed by A. Plaut.

La Genese des Sols en tant que Phénomène Géologique, H. Erhart (Masson). Reviewed by E. W. Berry.

15 June

Titanium, A. D. McQuillan and M. K. McQuillan (Academic Press). Reviewed by M. A. Hunter.

Water, U.S. Department of Agriculture. Reviewed by P. C. Duisberg.

Advances in Geophysics, vol. 2, H. E. Landsberg, Ed. (Academic Press). Reviewed by W. E. Smith.

Essentials of Biological and Medical Physics, R. W. Stacy, David T. Williams, R. E. Worden, R. O. McMorris (McGraw-Hill). Reviewed by F. S. Brackett.

The Psychology of Human Differences, L. E. Tyler (Appleton-Century-Crofts). Reviewed by D. E. Super.

22 June

The Torment of Secrecy, E. A. Shils (Free Press). Reviewed by P. H. Odegard.

Protoplasmatologia. Handbuch der Protoplasmaforschung, vol. II, F. J. Wiercinski (Springer). Reviewed by R. Bloch.

Advances in Carbohydrate Chemistry, vol. 10, M. L. Wolfrom and R. S. Tipson, Eds. (Academic Press). Reviewed by H. Gehman.

Atom und Psyche, E. F. von Eickstedt (Enke); *Die Selbstgestaltung des Lebendigen,* K. Friederichs (Reinhardt). Reviewed by L. von Bertalanffy.

Realms of Water, P. H. Kuenen (Wiley; Cleaver-Hume). Reviewed by E. D. Goldberg.

29 June

Stratigraphic Geology, M. Gignoux (Freeman). Reviewed by E. W. Berry.

The Crime of Galileo, G. de Santillana (University of Chicago Press). Reviewed by H. Dingle. This book was also reviewed in *The Scientific Monthly* [**82,** 43 (Jan. 1956)].

Applications of Spinor Invariants in Atomic Physics, H. C. Brinkman (North Holland; Interscience). Reviewed by P. G. Bergmann.

Nuclear Radiation Detectors, J. Sharpe (Methuen; Wiley). Reviewed by R. Hofstadter.

Protoplasmatologia. Handbuch der Protoplasmaforschung, vol. VIII, P. G. Lefevre (Springer). Reviewed by R. Bloch.

Thermal Power from Nuclear Reactors, A. S. Thompson and O. E. Rodgers (Wiley; Chapman & Hall). Reviewed by W. M. Breazeale.

Comparative Endocrinology of Vertebrates, pt. II, I. C. Jones and P. Eckstein, Eds. (Cambridge University Press). Reviewed by E. A. Adolph.

New Books

Demographic Yearbook 1955. 7th issue. Special topic: Population censuses. Statistical Office of the United Nations, New York, 1955. 781 pp. Cloth, $8.50. Paper, $7.

Analytical Exerimental Physics. Michael Ference, Jr., Harvey B. Lemon, Reginald J. Stephenson. University of Chicago Press, Chicago, Ill., rev. ed. 2, 1956. 623 pp. $8.

Plant Physiology. Meirion Thomas with the collaboration of S. L. Ranson and J. A. Richardson. Philosophical Library, New York, ed. 4, 1956. 692 pp. $12.

The Men behind the Space Rockets. Heinz Gartmann. Translated by Eustace Wareing and Michael Glenny. McKay, New York, 1956. 185 pp. $3.95.

World Aircraft Recognition Manual. C. H. Gibbs-Smith and L. E. Bradford. Putnam, London; De Graff, New York, 1956. 269 pp. $3.50.

Trace Elements in Human and Animal Nutrition. E. J. Underwood. Academic Press, New York, 1956. 430 pp. $9.50.

A Dictionary of Dietetics. Rhoda Ellis. Philosophical Library, New York, 1956. 152 pp. $6.

Therapeutic Use of Artificial Radioisotopes. Paul F. Hahn, Ed. Wiley, New York; Chapman & Hall, London, 1956. 414 pp. $10.

New Lives For Old. Cultural transformation—Manus, 1928–1953. Margaret Mead. Morrow, New York, 1956. 548 pp. $6.75.

Risk and Gambling. The study of subjective probability. John Cohen and Mark Hansel. Philosophical Library, New York, 1956. 153 pp. $3.50.

Bibliography of Solid Adsorbents, 1943–1953. An annotative bibliographical survey. NBS Circular 566. Victor R. Deitz. National Bureau of Standards, Washington, 1956 (order from Supt. of Documents, GPO, Washington 25). 1528 pp. $8.75.

Office Work and Automation. Howard S. Levin. Wiley, New York; Chapman & Hall, London, 1956. 203 pp. $4.50.

The Story of the Royal Dublin Society. Terence de Vere White. Kerryman, Tralee, Ireland 1955. 228 pp. 21s.

An Illustrated Catalogue of the Rothschild Collection of Fleas (Siphonaptera) in the British Museum (Natural History). With keys and short descriptions for the identification of families, genera, species and subspecies of the order. vol. II, *Coptopsyllidae, Vermipsyllidae, Stephanocricidae, Ischnopsyllidae, Hypsophthalmidae and Xiphiopsyllidae.* G. H. E. Hopkins and Miriam Rothschild. British Museum (Natural History) London, 1956. 477 pp. £6 6s.

Man, Culture, and Society. Harry L. Shapiro, Ed. Oxford University Press, New York, 1956. 380 pp. $7.50.

The Art of the Aqualung. Robert Gruss. Translated by Richard Garnett. Philosophical Library, New York, 1956. 66 pp. $2.75.

Uranium and Other Miracle Metals. Fred Reinfeld. Sterling, New York, 1956. 128 pp. $3.50.

Mental Hygiene. A survey of personality disorders and mental health. D. B. Klein. Holt, New York, rev. ed., 1956. 654 pp. $6.75.

Computers. Their operation and applications. Edmund Callis Berkeley and Lawrence Wainwright. Reinhold, New York; Chapman & Hall, London, 1956. 366 pp $8.

Advances in Enzymology and Related Subjects of Biochemistry. vol. XVII. F. F. Nord, Ed. Interscience, New York, 1956. 556 pp. $11.

Geochemistry of Iodine. Iodine in rocks, minerals and soils. Annotated bibliography 1825–1954. With review and tables. Chilean Iodine Educational Bureau, London, 1956. 150 pp.

Homological Algebra. Princeton Mathematical Ser. No. 19. Henri Cartan and Samuel Eilenberg. Princeton University Press, Princeton, N.J., 1956. 390 pp. $7.50.

Reactor Shielding Design Manual. Theodore Rockwell III, Ed. Van Nostrand, Princeton, N.J., 1956. 472 pp. $6.

College Chemistry. Andrew J. Scarlett. Holt, New York, 1956. 499 pp. $5.50.

The Human Body, Its Anatomy and Physiology. C. H. Best and N. B. Taylor. Holt, New York, ed. 3, 1956. 723 pp. $6.75.

Tombs, Temples and Ancient Art. Joseph Lindon Smith. Corinna Lindon Smith, Ed. University of Oklahoma, Norman, 1956. 349 pp. $5.

Histologie und Mikroskopische Anatomie des Menschen. W. Bargmann. Thieme, Stuttgart, Germany, rev. ed. 2, 1956 (order from Intercontinental Medical Book Corp., New York 16). 796 pp. $16.55.

What Flowering Tree Is That? Edwin A. Menninger. The Author, Stuart, Fla. 110 pp. $3.

Arctic Wilderness. Robert Marshall. George Marshall, Ed. University of California Press, Berkeley, 1956. 171 pp. $3.75.

General Zoology. David F. Miller and James G. Haub. Holt, New York, 1956. 550 pp. $6.95.

General Biology. Willis H. Johnson, Richard A. Laubengayer, Louis E. DeLanney. Holt, New York, 1956. 618 pp. $6.50.

Understanding Human Behavior. James L. McCartney. Vantage Press, New York, 1956. 258 pp. $3.50.

Handbook of Amphibians and Reptiles of Kansas. Misc. Publ. No. 9. Hobart M. Smith. University of Kansas Museum of Natural History, Lawrence, ed. 2, 1956. 356 pp. Cloth, $4; paper, $1.50.

E. A. Birge, a Memoir. G. C. Sellery. With an appraisal of Birge by C. H. Mortimer. University of Wisconsin Press, Madison, 1956. 221 pp. $3.50.

Spring on an Arctic Island. Katharine Scherman. Little, Brown, Boston, 1956. 331 pp. $5.

The Chemical Process Industries. R. Norris Shreve. McGraw-Hill, New York, ed. 2, 1956. 1004 pp. $11.50.

Fundamentals of Vibration Analysis. N. O. Myklestad. McGraw-Hill, New York, 1956. 260 pp. $6.50.

How Time Is Measured. Peter Hood. Oxford University Press, Geoffrey Cumberlege, London, 1955. 64 pp. $2.75.

Enzymes: Units of Biological Structure and Function. Henry Ford Hospital International Symposium. Oliver H. Gaebler, Ed. Academic Press, New York, 1956. 624 pp. $12.

Topology. E. M. Patterson. Oliver and Boyd, London; Interscience, New York, 1956. 128 pp. $1.55.

Creatures of the Deep Sea. Klaus Gunther and Kurt Deckert. Translated by E. W. Dickes. Scribner's, New York, 1956. 222 pp. $3.95.

Acridines. R. M. Acheson and L. E. Orgel. Interscience, New York, 1956. 409 pp. $12.50.